# The properties of hot and dense asymmetric nuclear matter

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The study of the equation of state (EOS) of hot asymmetric nuclear matter (ANM) has become a major area of research in nuclear physics and astrophysics during the last two decades. It plays an important role in the interpretation of nucleus-nucleus collision in which a hot and dense state of matter is formed. The many-body problem at finite temperatures has been considered by several authors within different approaches, such as the finite temperature Green's function method [1], the thermo-field method [2], or the Bloch–De Domicis (BD) diagrammatic expansion [3]. In the present study we will examine the properties of ANM like binding energy per nucleon and internal energy using a simple density dependent finite range effective interaction [4, 5]. In this work the internal energy of the system $\mathrm{F} \to \mathrm{F}/\mathrm{A}$ is computed by using the entropy of the free Fermi gas with effective mass of the symmetric nuclear matter ($m^*$) [6] where the internal energy of nuclear matter is defined by

$$\mathrm{F} = \mathrm{E}(\rho, \beta, \mathrm{T}=0) - \mathrm{T}\,\mathrm{S_T}, \quad \text{------------ (1)}$$

Here $\mathrm{E}(\rho, \beta, \mathrm{T}=0)$ is the total energy at $\mathrm{T}=0$, $\mathrm{S_T}$ is the entropy of the system at temperature $\mathrm{T}$, $\beta$ be the isospin asymmetry $\beta = \frac{\rho_n - \rho_p}{\rho}$, where $\rho_n$ and $\rho_p$ are the neutron and proton densities respectively and total density $\rho = \rho_n + \rho_p$. In addition, thermal effects are treated in a low-temperature limit of the internal energy. Starting from eq. (1), in the low-temperature limit the energy and entropy behave as

$$\mathrm{E}(\rho, \beta, \mathrm{T}) = \mathrm{E}(\rho, \beta, \mathrm{T}=0) + \mathrm{a}\,\mathrm{T}^2 \quad \text{----------------- (2)}$$

and $\mathrm{S_T} = 2\,\mathrm{a}\,\mathrm{T}$, respectively, where a is the so-called level density parameter. Therefore, for the internal energy we have the following expression:

$$\begin{aligned}\mathrm{F} &= \mathrm{E}(\rho, \beta, \mathrm{T}=0) + \mathrm{a}\,\mathrm{T}^2 - 2\,\mathrm{a}\,\mathrm{T}^2 \\ &= \mathrm{E}(\rho, \beta, \mathrm{T}=0) - \mathrm{a}\,\mathrm{T}^2 \end{aligned} \quad \text{------------------ (3)}$$

$$\text{with } a(\rho) = \frac{1}{4}\pi^2 \left( \frac{2m^*(k_f)}{\hbar^2 k_f^2} \right) \quad \text{--------- (4)}$$

where the level-density parameter 'a' is a function of nucleon effective mass $m^*$ at T= 0 MeV with $\mathrm{k} = \mathrm{k_f}$. In the Fermi-gas model there is a very small isospin dependence of the level-density parameter

$$a = \frac{\pi^2}{6}\left(g_n + g_p\right) \propto A^{2/3}\left(N^{1/3} m_n + Z^{1/3} m_p\right) \approx mA\left[1 - \frac{1}{9}\left(\frac{N-Z}{A}\right)^2\right] \quad \text{-----------------(5)}$$

By using Eq. (3) the internal energy [7] of the system at temperature T is defined by

$$\mathrm{F} = \mathrm{E}(\rho, \beta, \mathrm{T}=0) - \frac{\mathrm{T}^2}{6}\left(\frac{2m^*}{\hbar^2}\right)\left(\frac{3\pi^2}{2}\right)^{1/3} \rho^{-2/3} \quad \text{--------------- (6)}$$

where $m^*$ be the effective mass of the nucleon at zero temperature. In Fig.1, the internal energy of ANM is plotted as a function of density at temperature 10 and 20 MeV and at $\beta = 0.4$ using eq. (6).

It is observed that the internal energy increases with increase in density and the value of energy is less for higher temperature. In Fig.2, the total energy per nucleon of ANM is plotted as a function of density at temperature 10 and 20 MeV and at $\beta = 0.4$ using eq. (2). It is observed that the energy increases with increase in density and the difference in energy at different temperatures diminishes at higher densities.

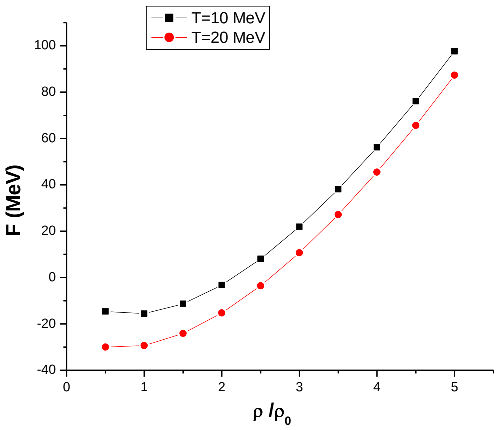


Fig: 1

**Fig.1:** The internal energy for ANM as a function of density at T = 10 and 20 MeV and β=0.4.

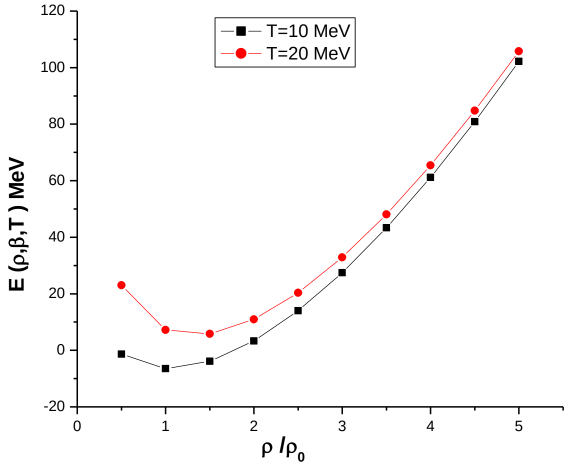


Fig: 2

**Fig.2:** The energy per nucleon for ANM as a function of density at T = 10 and 20 MeV and β=0.4.

## References


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