INTRODUCTION

The equation of state (EOS) gives the pressure as a function of temperature and density of a physical system, and is related to both fundamental physics and the applications in; gases, condensed matter, astrophysics and elementary particle theory.

Furthermore(1), as mechanics was extended to take into account of relativity and quantization, so the equation of state had developed to describe states of matter in extreme density and temperature domains.

The study of the equation of state is one of the most important problems in physics in the first of the nineteenth century. There is now high priority in modern physics to solve the numerous deficiencies in our knowledge about the equation of state. The development of the equation of state is again sought to meet the needs of rapidly advancing modern physics of extreme state of matter.

In nuclear physics, the equation of state is used to study the properties of nuclear and neutron matter. The nuclear matter is an infinite uniform system of nucleons (neutrons and protons) interacting via a strong nuclear force (nucleon-nucleon (n-n) interaction). Such static properties of nuclear matter, like binding energy, asymmetric energy, incompressibility....etc., can be determined successively by EOS. Furthermore, at finite temperature, the thermal properties of nuclear matter can be studied, such that, free energy, entropy, effective mass, chemical potential, and all possible phases in which the matter may exist.

In neutron matter the equation of state is a very useful tool for studying the properties of neutron stars. It is an excellent example of neutrons existing in a specific volume under a high conditions of temperature and density. In astrophysics the equation of state can be used to study the evolution of stars. So the universe evolution can be studied.

There are two types of the equation of state, one of them is the soft EOS, in which the pressure increases smoothly with increasing density especially at high density. The other type of the equation of state is the stiff EOS, which is characterized by the sharp increasing of pressure with increasing density.

There are different theories and models used to study the nuclear and neutron matter, such as : Hartree-Fock (HF)[2-4], Brueckner's theory[5-7], relativistic mean field theory (MFT)[8-10], variational methods[11-14], and Thomas-Fermi (TF) model[15-18]. In these models different types of potentials are used, some of them are Skyrme potential[19,20], Reid potential[21], two- and three-(n-n) potentials[14], Paris-potential[22], and Seyler-Blanchard potential[15,16].

In Hartree-Fock (HF) method, the density and kinetic energy are expressed in terms of the wave functions (single particle states) and then the total energy is minimized with respect to these wave functions under the constrain that they are orthogonal. This minimization leads to the non-linear HF-equations which have to be solved self-consistently.

Vautherin and Brink[4] have used Skyrme density-dependent effective n-n interaction to perform the Hartree-Fock calculations for spherical nuclei. They studied the relation between the parameters of Skyrme force and various general properties of nuclear matter and finite nuclei. From which, they concluded that the Skyrme's interaction provides, (with only five parameters) a very simple parametrization of the nuclear effective interaction, which already contains all the ingredients necessary to give a good description of the average nuclear field.

Moszkowski[23,24] has done some HF-calculations with both spin-dependent[23] and spin-independent[24] potentials, and found that the binding energy and the volume asymmetric energies are not altered by spin-dependence of the interaction, but the surface energy alters. He deduced high value of incompressibility (K=315 Mev), which is a characteristic of the Skyrme potential.

Vautherin[25] has done some HF calculations with Skyrme potential and gave a numerical solution for HF-equations. He concluded

that the Skyrme force with HF calculations gives accurate results and it can be related to nuclear matter theory based on a realistic force.

Weber and Weigel[26] have studied the nuclear and neutron matter in the framework of Hartree (HI...HIV) and Hartree-Fock (HFI,HFII). It turns out that the equation of state calculated with HIV (HFI) is the softest (stiffest) one. Also they concluded that approximations that contain no dynamical correlations give relativity stiff EOS, and they found a phase transition for nuclear matter in the range Tc=14-21 Mev. But the phase transition of neutron matter appears with Hrtree approximations(T_c=9 Mev) is removed in Hrtree-Fock approximation.

Brueckner's theory[7] in the local-density approximation, states that "in the lowest order, the interaction between two nucleons in a finite nucleus is given by the nuclear matter G-matrix calculated at the density of the center of mass of the nucleon pair".

The Dirac-Brueckner approach[27] is an approximation covariant theory, which includes the modification of the Dirac spinors of the nucleons inside the medium, where the nucleon bare mass is replaced by the effective mass.

A relativistic Dirac-Brueckner calculation has been performed by ter Haar and Malfiet[28] using a one-boson-exchange interaction. However, their calculations are restricted to zero temperature. They observe a stiff equation of state.

Das et al[29,30] have developed a fully self-consistent model which is a generalization of the Brueckner theory to finite temperature in which scattering to intermediate states is taken into account and the degeneracy and the single particle potential are calculated self-consistently.

Das et al[31] have used their extension[29,30] of Brueckner theory to calculate some thermodynamics quantities for asymmetric nuclear matter. They found the occurrence of a liquid-gas transition at $T_C = 9$ Mev which is smaller than that obtained by Baldo et al[32] and Friedman and Pandharipande[14] . However ter Haar and Malfiet[33] found T_C below 10 Mev from their Dirac-Brueckner calculations.

Cugnon et al[34] have calculated the neutron matter properties using their extended Brueckner approach with Paris potential supplemented by a three-body force. The obtained binding energy that turns out to be very close to that calculated vartionally[14] . They obtained a rather stiff equation of state, capable of producing neutron stars with masses up to 1.8 of solar mass (Mo), which confirm the observation of Glendening[35], saying that "the nuclear matter EOS should be stiffer than that suspected by Malfliet and ter Haar[36] , and Brown and Osnes[37] in order to comply with observed neutron star masses.

Li et al[38] have studied the properties of dense nuclear and neutron matter in the framework of Dirac-Brueckner calculation using Bonn A, B and C potentials . They found that around the saturation point, the microscopic equation of state derived from Bonn A potential agrees with the phenomenological EOS of the Skyrme parametrization, but at high density, large difference occur.

The mean-field theory (MFT) is one of the most frequently used approaches for the description of relativistic nuclear (neutron) matter. Serot and Walecka[10] gave a review article to the details, with further references, of the mean field approximation.

Weber and Weigel[26] have studied the nuclear matter as well as the neutron matter in the framework of a relativistic nuclear field theory at finite temperature. They compared the results obtained by MFT and that of HF or relativistic HF (RHF). They concluded that approximations with no dynamical correlations (e.g MFT, RHF ..etc.) with linear field equations gives relatively stiffer equation of state, but inclusion of self-interactions leads to a softer behaviour of the EOS. However, inclusion of dynamical correlations seem to have the same tendency, since they get much smaller incompressibilities.

For neutron matter, Weber and Weigel[26] have obtained great differences between MFT and HF approach, and the phase transition of neutron matter appears in MFT (T_C = 9 Mev) is removed in the HF approximation.

Zimanyi and Moszkowski (ZM) [39] have proposed a new version of relativistic mean field theory differing from that of the standard Welecka model[8], only in the form of coupling of the nucleons to the scalar meson.