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Influence of the tetraneutron on the EoS under core-collapse supernova and heavy-ion collision conditions

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Light (e.g. deuterons, tritons, helions, α−particles), and heavy (pasta phases) nuclei exist in nature in core-collapse supernova matter and neutron star (NS) mergers, where temperatures of the order of 50 to 100 MeV may be attained. In the NS inner crust, that is under different conditions of temperature, density and asymmetry, these heavy clusters should also be present. The appearance of these clusters can modify the neutrino transport, and, therefore, consequences on the dynamical evolution of supernovae and on the cooling of proto-neutron stars are expected. However, a correct estimation of their abundance implies that an in-medium modification of their binding energies is precisely derived. At such temperatures, other exotic degrees of freedom, such as hyperons, Δ−isobars, or even resonant states of four neutrons, may appear. Recently, such a resonant state of four neutrons (tetraneutron) with an energy of E4n = 2.37±0.38(stat) ± 0.44(sys) MeV and a width of Γ = 1.75±0.22(stat) ± 0.30(sys) MeV was reported. In this work, we analyze the effect of including such an exotic state on the yields of other light clusters. We use a relativistic mean-field (RMF) formalism, where we consider in-medium effects in a two-fold way − that is, via the couplings of the clusters to the mesons, and via a binding energy shift − to compute the low-density equation of state (EoS) for nuclear matter at finite temperature and fixed proton fraction. We consider five light clusters − namely deuterons, tritons, helions, α−particles, and 6He − immersed in a gas of protons and neutrons, and we calculate their abundances and chemical equilibrium constants with and without the tetraneutron. We also analyze how the associated energy of the tetraneutron would influence such results. We find that the low-temperature, neutron-rich systems are the ones most affected by the presence of the tetraneutron, making NSs excellent environments for their formation. Moreover, its presence in strongly asymmetric matter may increase the proton and α−particle fractions considerably. This may have an influence on the dissolution of the accretion disk of the merger of two NSs.

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