Reexamination of a novel determination of density, temperature, and symmetry energy based on a modified Fisher model

R. Wada, X. Liu, W. Lin, M. Huang, and H. Zheng

In 1967, M.E. Fisher proposed a droplet model of a second order phase transition to describe the power law behavior of the "fragment" mass distribution around the critical point for a liquid-gas phase transition [1]. In the early 1980s, based on the Fisher model, the Purdue group generated a novel classical droplet model, which was the so-called modified Fisher model (MFM), and introduced it into nuclear physics [2–4]. Recently, a series of experimental and theoretical investigations based on the MFM have been carried out to explore the symmetry energy of the nuclear equation of state and the critical behavior of hot fragmenting matter [5-32].

However, the MFM formulation from the pioneering works of the Purdue group contained a mistake which originated from the wrong sign in front of the mixing entropy term and caused some errors. In this study, we address this mistake in their formulation, and quantitative analyses are given for the errors originating from the mistake in typical MFM-related studies.

In MFM, the yield of isotope with (I,A; I=N-Z) can be described as

$$Y(I,A) = Y_0 \, A^{-\tau} \exp\left[\frac{W(I,A) + \mu_n N + \mu_p Z}{T} + S_{\mathrm{mix}} \right].$$

W(I,A) is free energy, μ_n and μ_p are Chemical potential of neutron and proton. S_{mix} is the mixing entropy, which can be described by $S_{\mathrm{mix}}(N,Z) = - [N \ln(N/A) + Z \ln(Z/A)]$ in a classical form. In the original form of Purdue group, S_{mix} is defined as $S_{\mathrm{mix}}(N,Z) = N \ln(N/A) + Z \ln(Z/A)$ and $S_{\mathrm{mix}}(N,Z)$ has a negative value.

The errors from the mistake in the results of the previous MFM-related studies, such as isotopic yield distribution, isobaric yield ratios, isoscaling, m-scaling, self-consistent determination of density, symmetry energy, and temperature, and density and temperature determination related to the IMF freezeout, are quantitatively evaluated. It is found that the errors originating from the mistake in sign of the mixing entropy term are generally small and even have no effect in some cases. The results and conclusions in the original papers are generally valid.

These results have been published in Ref. [33].

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