MULTIPLICITY AND CHARGE DISTRIBUTIONS OF FRAGMENTS PRODUCED IN MULTIFRAGMENTATION OF NUCLEAR SYSTEMS

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Multifragmentation is observed experimentally in hadron-nucleus and nucleus-nucleus collisions as well as in the low energy antiproton nuclear absorption. This process is beeing studied theoretically by both macroscopic and microscopic approaches [1]. So far, however, the reasons for the occurrence of this process have not been completely clarified. It is interesting to compare the characteristics of the multifragmentation processes which occur under different conditions. A large number of charged fragments are formed in a many-body decay process such as multifragmentation. The multiplicity and the charge distributions of the fragments which are formed can serve as the primary characteristics of this many-body decay. Calculations of these characteristics are extremely complicated in all physical models; they depend on the particular features of each model. Thus, as a first step in this research it is worthwile to base the calculations on some obvious principle which would make it possible to find the distributions of multiplicity and charges for a given excited nuclear system. Such a principle does exist; it is the conservation of the integer nature of the electric charge in the course of any nuclear decay. Mathematically, this principle can be expressed in an extremely simple way:

$$Z_0 = \sum_{i=1}^{n} z_i. \tag{1}$$

The primary charge Z_0 of the nuclear system is partitioned into a sum of integer terms z_i, the number of which, n, is the multiplicity of the charged particles for the given partitioning. All the z_i, as well as Z_0 and n are positive integers. A highly excited nuclear system can decay with any set of z_i and n values, which satisfy condition (1). Accordingly, it is reasonable to start with the *a priory* assumption that the appearance of all sums in (1) is equiprobable. Working with that assumption alone, we can derive multiplicity and charge distributions for all partitionings. The problem reduces to one of analyzing the partitionings, which can be either ordered or disordered, of a positive integer [2]. For ordered partitionings, the normalized multiplicity distribution is expressed in terms of binomial coefficients,

$$\omega(n, Z_0) = 2^{1-Z_0} \cdot C_{Z_0-1}^{n-1}, \tag{2}$$

while the normalized charge distribution is written

$$\omega(z, Z_0) = 2^{-z} \cdot (Z_0 - z + 3) \cdot (Z_0 + 1)^{-1}. \tag{3}$$

There are no analytic expressions for the corresponding distributions for disordered partitionings; numerical methods are used to calculate them [3]. Fig.1 shows mormalized multiplicity distributions for ordered partitionings (solid curve) and for disordered ones (dashed curve). Fig.2 shows normalized charge distributions for ordered and disordered partitionings, again by solid and dashed curves respectively. The curves in these figures are plotted for the values $Z_0 = 39$. This value was selected so that the results could be compared with experimental results [4] on the bombardment of a ${}^{45}_{21}Sc$ target by ${}^{40}_{18}Ar$ ions accelerated to an energy in the range $35 \div 115$ Mev/nucleon. The charge distributions of fragments with charges $1 \leq z \leq 12$ were measured by a 4π detector for eight values of the energy near the boundaries of the specified interval and in its interior. The charge distributions measured for the interval $3 \leq z \leq 12$ were approximated by an exponential function $C_\lambda \cdot \exp(-\lambda z)$ and by a power law $A_\tau \cdot z^{-\tau}$. It was found that the exponential expression corresponds to the upper part of the energy interval, and the power law to the lower part. The values for the coefficient λ and the power τ increase with the energy.

Examining the theoretical charge distributions in Fig.2 as the result of numerical simulations, we approximated them by the least-squares method, again by exponential and power-law functions, for the same charge interval $3 \leq z \leq 12$.

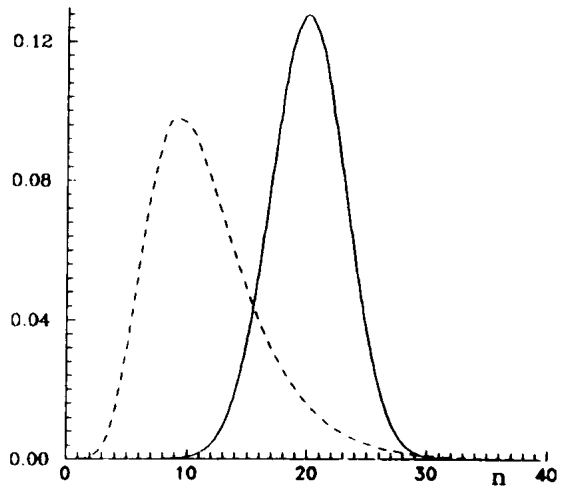

Fig.1. Normalized distributions of the multiplicity of charged fragments during the decay of a nuclear system with Z_0=39

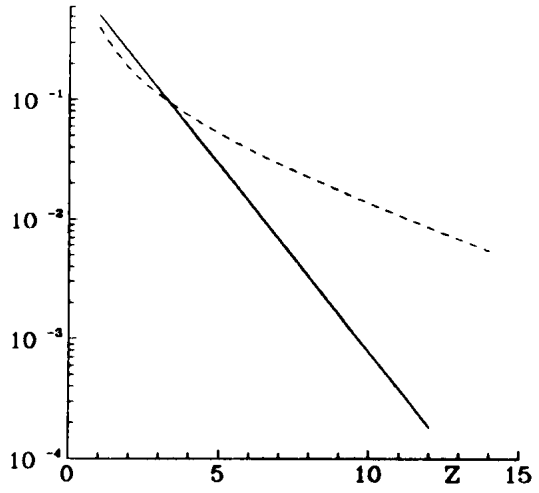

Fig.2. Normalized charge distributions of fragments during the decay of the nuclear system with Z_0=39

The approximation by a power law was carried out under the assumption that all 10 points being approximated have a 10% error, while a 1% error was assumed in the approximation by the exponential function. It turns out that for ordered partitionings the charge distribution can be approximated better by an exponential law, while the power law is better for the disordered partitionings. The values found for the parameters, $\lambda = 0.722 \pm 0.001$ and $\tau = 1.82 \pm 0.07$, lead to values of χ^2 per degree of freedom of 0.9/8 and 7.2/8, respectively. The calculated parameter values agree satisfactorily with their experimental values: λ toward the upper boundary of the energy interval and τ toward the lower one. An agreement between

the theoretical and experimental results in the same boundary regions of this energy interval is also found for the average multiplicities: 20 and 21 for ordered partitionings and 11.6 and 14 for the disordered ones. We should conclude from these comparisons that the method proposed here for calculating multiplicities and charge distributions is suitable for real nuclear systems which undergo multifragmentation. It would be interesting to look at some other experimental results and to compare them with theoretical distributions for other values of Z_0. That is not possible at the moment, however, since in all other experiments of which we are aware the nuclear systems that underwent multifragmentation usually had numerous values of Z_0. The experiments of Ref.[4] were particularly welcome in that collisions of nearly symmetric nuclei of a beam and a target were used; the beam and target nuclei differed only very slightly in charges and mass numbers. As a result, the charge Z_0 of the decaying nuclear system was effectively fixed.

The calulation method proposed here can also be used to calculate correlations between the multiplicity and charge distributions of the fragments which are produced.

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