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NEW STATISTICAL FUNCTION FOR THE ANGULAR DISTRIBUTION OF EVAPORATION RESIDUES PRODUCED BY HEAVY IONS

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The problem of the angular distribution of evaporation residues (EVR) with heavy-ions reaction has been studying for many years[1]. However , the interest on this problem increased during the last years due to the development of new electromagnetic separators for the study of the evaporation residues from heavy-ion induced fusion-evaporation reactions [2-7] . The angular distribution is important for separators because the acceptance of the separator during the study of determined reaction , depends on the widths of the angular distribution of the EVR recoiled out from the target .

For thick targets the angular distribution depends fundamentally on the multiple scattering of the EVRs by the nuclei of the target . But , for thin targets (when the target thickness much less than the average range of EVRs in this target) , the neutron evaporation can play an important role as well .

Experimentally , the angular distribution $R_{exp}(\theta_i)$ is known to be determined by counting the number of nuclei impinging on some disks whose radii are defined by

the expression L*sin(θ_i) , where L is the distance from the target to the disk and θ_i is a certain mean angle (expressed in degrees here) between the central trajectory of the beam and the direction of the central circle inside the disk "i" . In this case , the number of counts in each disk will depend on the angle (through sin (θ_i)) and on certain other function of θ .

Using the function $R_{exp}(\theta_i)$, we can determine the experimental mean squared angle $<\theta^2>_{exp}$ by the expression :

$$\langle\theta^2\rangle_{exp} = \sum \theta_i^2 * R_{exp}(\theta_i) \qquad (1)$$

It is well known that the parameter $\langle\theta^2\rangle$ is very important because , under the assumption of isotropic neutron evaporation , it is possible to obtain an expression which establishes a relation between this value and some parameters of the studied reaction . In a first approximation , this relation takes the form :

$$\langle\theta^2\rangle = 2 * X * E_n / (3 * A_b * E_b) \qquad (2)$$

where X is the number of emitted neutrons , E_n is the mean energy of these neutrons, A_b and E_b are the mass number and the laboratory bombarding energy of the projectiles respectively . Usually[8] the function R(θ) is modelled using a Gaussian function combined with the function sin(θ) . Nevertheless , with this combination one can not obtain a mean square value of θ corresponding to the experimental one because , for the normal distribution , the mean square value coincides with the variance .This detail explains the discrepancy in the expression of the $\langle\theta^2\rangle$ that is observed in some works [9,10].

We have found a new statistical function which describes the experimental results in a natural form and gives a better concordance between the experimental and calculated values .This function is determined only by one parameter , namely, the $\langle\theta^2\rangle$ value :

$$R(\theta) = 360/(\pi * <\theta^2>) * \sin(\theta) * e^{-\theta^2/<\theta^2>} \qquad (3)$$

The function $R(\theta)$ satisfies the following conditions :

$$\int_0^{90} R(\theta) * d\theta = 1 \qquad (4)$$

$$<\theta^2> = \int \theta^2 * R(\theta) * d\theta \qquad (5)$$

The integral is taken to 90° however , since under generally encountered experimental conditions , the function $R(\theta)$ goes rapidly down to zero for values of θ taken three or four times of the value $\sqrt{\langle\theta^2\rangle}$.

For illustrating how the function $R(\theta)$ works , in figs.1-4 we compare some experimental results obtained for the angular distributions of the nuclei after evaporation of X neutrons [9,11] with the calculated distribution involving the experimental parameter $\langle\theta^2\rangle_{exp}$.

Represented in figs.1-3 are angular distributions of the residual nuclei ^{149g}Tb and ^{149,151}Dy produced by the reactions[9] :

1 ^{146}Nd + ^{11}B (104 Mev) ⟶ ^{149g}Tb + 8 n
2 ^{140}Ce + ^{16}O (111 Mev) ⟶ ^{149}Dy + 7 n
3 ^{144}Nd + ^{12}C (94 Mev) ⟶ ^{151}Dy + 5 n

In the figures the experimental results (crosses) are compared with the calculated ones (solid lines)obtained by using the function $R(\theta)$.

In fig.4 the experimental[11] angular distribution of the nuclei with atomic number A=125 obtained from the reaction ^{nat}Ag + ^{22}Ne are compared with the calculated

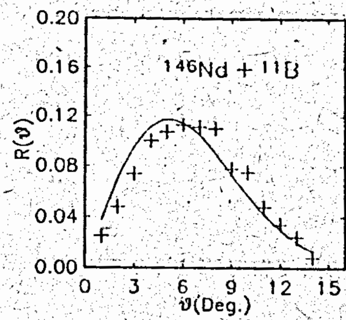

Fig.1

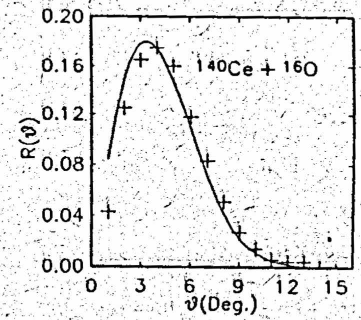

Fig.2

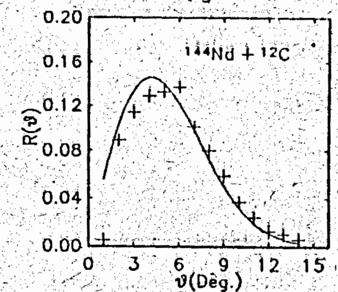

Fig.3

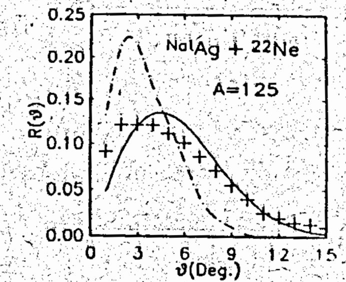

Fig.4

distributions using the Gaussian distribution (point-dashed)[11] and using the function $R(\theta)$(solid line) .

We stress there is no fitting of any kind , but only the calculation of angular distributions using the function $R(\theta)$ with experimental parameters $\langle\theta_i^2\rangle_{exp}$.

The function $R(\theta)$ is very simple and it describes the process in a natural form . Nevertheless the origin of the coefficient $(360/\pi)$ is not quit clear yet . But , in any case , it was very nice to find it .

The function $R(\theta)$ is particularly useful to describing angular distributions when in the experiment are detected all the particles arriving under the angle θ . It is very useful also for the evaluation of the acceptance of collecting the EVR of determined heavy ion induced reaction , using electromagnetic separators .

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