EMISSION OF CLUSTERS IN PRECOMPOUND REACTIONS

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ABSTRACT

The preformed model (PFM), the quasi-free-scattering model (QFSM) and the coalescence model (CLM) suggested for the description of cluster emission in precompound reaction theory are described and underlying physical assumptions discussed. Only energy distribution of clusters is considered.

INTRODUCTION

Soon after appearance of the Exciton model[1] attempts were made to apply its inovative idea on reaction mechanism to the emission of clusters[2-6]. All these models and their modifications are characterized by the proposed mechanism of cluster formation. In the following we shall not consider the model with no explicit clusterization[2,3] because its contribution to the cluster emission is too small[7]. Remaining models are based on two distinct assumptions: (i) the cluster is preformed in the target nucleus (PFM and QFSM) and (ii) excited nucleons are involved in the cluster formation process.

PREFORMED MODEL

This model[4] assumes that the cluster (namely α - cluster) is preformed in the target nucleus. Due to projectile - - target nucleus interaction the preformed cluster can get excited and eventually emitted from the composite system. The α-cluster is visualized as a group of four strongly correlated nucleons with $g_\alpha \approx g/4$ single particle state density (and similarly corresponding hole). If not emitted it interacts with other nucleons as four uncorrelated nucleons[8]. The last assumption was introduced in order to bring PFM in accord with α induced reactions indicating the dissociation of incoming α. The key point of the model is the so-called preformation factor φ representing the probability that the preformed α-cluster will be excited. Corresponding expression for the emission rate is

$$W_{\alpha}(m,\varepsilon_{\alpha})d\varepsilon_{\alpha}=\frac{\varphi K_{m-1}^{\alpha}\,\omega_{m-1}(U)}{\left[(1-\varphi)K_{m}^{\nu}+\varphi K_{m}^{\alpha}\right]\omega_{m}(E)}\,\frac{\mu_{\alpha}}{\pi^{2}\hbar^{3}}\,\varepsilon_{\alpha}\sigma_{inv}(\varepsilon_{\alpha}), \qquad 1$$

where coefficients K should justify the use of one-component state density instead of 3-component one. The use of eq.(1) leads to quite large values for φ which can hardly be accepted[9]. It was shown[10] that eq.(1) has several shortcomings and conclusion was made that eq.(1) should not contain φ and K's and g_{α} should be redefined. While the spectral shape is not changed by these modications the factor φ is reduced at least ten times.

QUASI-FREE-SCATTERING MODEL

The preformed α-cluster represents again the basic assumption of this model[6]. In contrast to PFM the concept of the composite nucleus state density is fully abandoned with reference to the pronounced anisotropy of energy distribution for (nucleon,α) scattering process[6] inside the composite nucleus. This invalidates the "equiprobability assumption" on which the Exciton model is based. A master equation is solved to estimate the occupation probability of energy bins into which the composite system is divided. The probability per unit time of a collision between particles in different bins is based on the angle averaged free scattering cross section corrected for Pauli principle. Collision probability nucleon-α is modified by the factor φ having the same meaning as in PFM. In addition, in order to account for possible break up of α-cluster the factor B is introduced. Thus Bφ represents the probability that preformed α will be scattered as such in (nucleon,α) collision. Expected enhanced α-clustering in low density region is taken into account by assuming a relatively small Fermi energy for α-cluster. There are other assumptions involved which make the model quite unclear. Important feature of the model is, we believe, that values of φ (0.2-0.3) and B ($\sim$0.5) gained from comparison with experimental data[6] are rather high and difficult to interpret.

COALESCENCE MODEL

In this model[5] the cluster is formed from excited nucleons in each n-exciton state of the composite nucleus. The clusterization process is assumed to be a multistep proces characterized by the probability γ_β that p_β excited nucleons will eventually form β-cluster. This quantity is formally understood as an overlaping integral of β-particle and p_β nucleons. Within the framework of the Exciton model the emission rate for β-clusters can be estimated as

$$W_\beta(p,h,\varepsilon_\beta)d\varepsilon_\beta=\left[\frac{\omega_{p-p_\beta,h}(U)\,\omega_{p_\beta,0}(\varepsilon_\beta+B_\beta)}{\omega_{p,h}(E)}\gamma_\beta d\varepsilon_\beta\right]\lambda_{SP,\beta}(\varepsilon_\beta), \qquad (2)$$

where the term in brackets represents the number of β-clusters in the composite system and $\lambda_{SP,\beta}$ is the single particle emission rate calculated using the detailed balance. The use of state density in eq.(2) is not at variance with the result of ref.[6] because only nucleons are involved in the intranuclear collision process. Effects connected with preferential excitation of nucleons near the nuclear surface[6] can be taken into account using suitable expression for ω's[11]. Comparison of eq.(2) with experimental spectra show[12,5] that $\gamma_\alpha \lesssim 10^{-3}$ for heavier nuclei which is in qualitative agreement with independent result of ref.[13].

CONCLUSION

The variety of approaches to describe the cluster emission in precompound reaction theory confirm again the old knowledge that this problem is very complicated and not yet satisfactorily solved. Today it is hardly possible to decide which model is to be prefered. Rather, we feel, an extensive unbiased intercomparison of existing models is needed using a representative set of experimental data. This should allow to extract more unambigous physical information on reaction mechanism and to determine the limsts of these models.

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