LIGHT PARTICLES EMISSION FROM HOT, ROTATING, COMPOUND NUCLEI * **

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The competition between fission and n, p and α–particle emission is studied. The fission process is described by a Langevin equation coupled to the Masters equation for particles evaporation. The significant influence of the nuclear deformation, isospin dependence of the nuclear charge radius and of the initial spin distribution on the prescission particles multiplicities is found.

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1. Introduction

The present discussion of the decay of compound nuclei is a continuation of our previous works [1, 2]. Our aim is a step wise improvement of the general theory in order to reach a quantitatively reliable description of the decay of hot nuclei. We assume that the particle emission is described by the Weißkopf theory [3], and that the nuclear fission is a transport process [4]. The emission of photons will be neglected. The Langevin equation is used to describe the fission process and it is dynamically coupled with the Masters type equation for the light particles evaporation.

We give here a more careful study of dependence of the evaporation probabilities on the deformation of nucleus and its isospin. Our first estimates show that the isospin dependence of the nuclear charge radius found in Ref. [5] could help to bring the theoretical estimates of the number prefission charge particles obtained in Ref. [1] toward the experimental data [6].

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2. Results

We study the decay of compound nuclei of isotopes of $_{64}$Gd and of $_{70}$Yb. We have selected these nuclei because a careful experimental investigation of their decays is available [8, 6] and because they are known to exhibit large ground state deformations. Consequently, it is of special interest to investigate the influence of deformation on the emission of n, p and α particles from excited states of these nuclei.

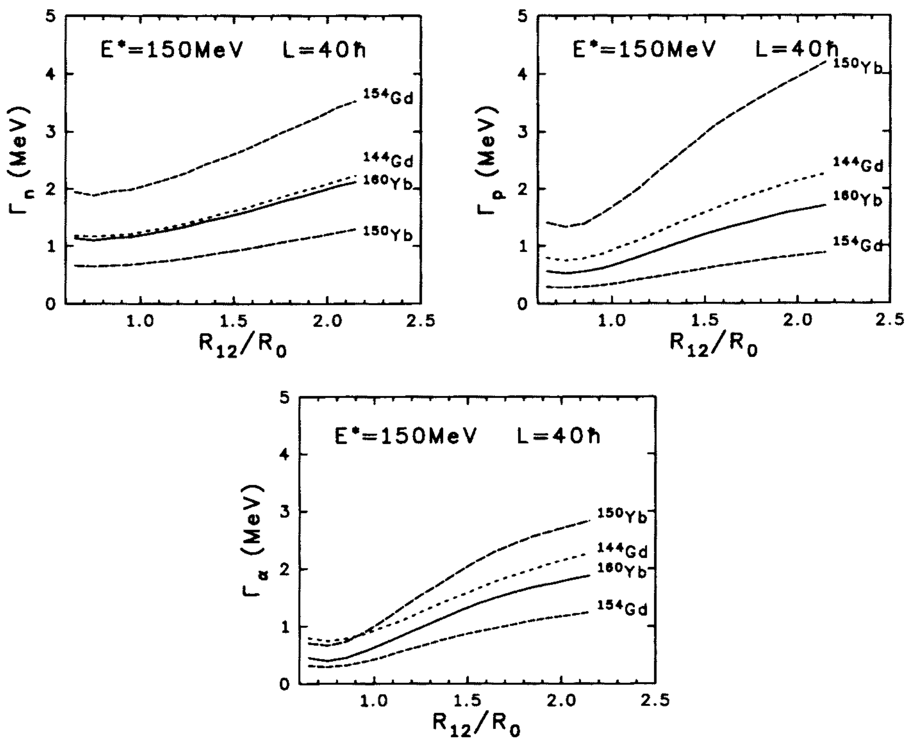

Fig. 1. Emission widths for neutrons (left), protons (right) and alphas (below) emitted from different isotopes of Gd and Yb at $E^* = 150$ MeV and $L = 40\ \hbar$ as a function of the elongation.

In Fig. 1, the deformation dependence of emission width for n, p and α is shown for two different isotopes of both $_{64}$Gd and $_{70}$Yb. We chose these 4 nuclei in order to study the isospin and deformation dependence of the emission widths for n,p, and α. The average excitation energy $E^* =$ 150 MeV and angular momentum $L = 40\ \hbar$ is assumed. All the emission rates are seen to grow as a function of increasing deformation. This trend can be easily understood as for increasing deformation the transmission occurs through a larger surface. We notice, however, that the emission width for α–particles increases more steeply than the one for n and p for lower excitation energies. This is due to the fact that, as the nucleus is elongated, the barrier height for charged particles is reduced in the section of the surface which is farther away from the nuclear center and increased in the section which is closer to the center. The section where the barrier is diminished is larger than the section where it is increased. Consequently, the emission rate for charged particles increases faster than the one for neutrons. Assuming an equal population of the initial angular momenta, we have estimated the average of the n, p and α-multiplicities. The resulting values are compared in Table I with the experimental data taken from Ref. [6]. All parameters of the model are standard (see *e.g.* [2]). We only have to assume some preformation factor $f_\alpha = 0.2$ for alpha particles in order to reproduce their experimental number. This goes into the right direction since our calculations show that α particle emission is strongly enhanced by rotation and deformation effects.

TABLE I

Results of prescission neutron, proton and alpha multiplicity model calculations for ^{160}Yb at excitation energies 251 MeV and 293 MeV compared with the experimental data taken from Ref. [6]. The theoretical results are averaged over all initial angular momenta with a weight proportional to the corresponding fission rates.

	$E^* = 251$ MeV		$E^* = 293$ MeV	
ν	model	exp.	model	exp.
n	5.98	6.10± 1.5	7.80	8.50± 1.6
p	0.94	0.51± 0.07	1.19	0.70± 0.08
α	0.58	0.48± 0.07	0.66	0.75± 0.08

Also it is seen in Table I that our estimate of the number of prefission protons is too large. One of the possible origin of these discrepancies is neglecting of the isospin dependence of the nuclear charge radius in the proton and alpha potentials. In the evaporation model one assumes that the nuclear charge radius is described by the function:

$$R_{ch} = r_0 A^{1/3} . \tag{1}$$

It is simplification and completely neglects the isospin dependence of the radius. From our analysis of the experimental mean square charge radii made in Ref. [5] we have got the following formula:

$$R_{ch} = r_0 A^{1/3} \left(1 - \alpha \frac{N-Z}{A}\right) , \tag{2}$$

with $r_0 = 1.25$ fm and $\alpha = 0.2$. The new formula for the charge radius will increase significantly the potential barrier for emission of protons and alphas from the neutron reach nuclei. This effect will decrease the number of the prefission charge particles. Our first estimates show that the taking into account this isospin dependence in the Coulomb potential reduces the multiplicity of prefission protons up to about 40%.

3. Summary

Our results demonstrate the importance of nuclear deformation on the evaporation of light particles from strongly excited nuclei. This dependence as well as the dependence of the emission width on the isospin of emitters plays an important role also for the competition between fission and particle emission.

The fission probability depends very sensitively on the angular momentum, as we have already emphasized in Ref. [2]. Due to this strong dependence of the fission probability on the initial angular momentum, it becomes very important to get precise information on the angular momentum distribution of the initial ensemble of compound nuclei. The outcome of the competition between light particle emission and fission may depend strongly on the initial angular momenta. Consequently, we have to try to obtain theoretical information on the angular momenta of the initial nuclei by treating the fission process dynamically [9, 10].

We hope that the angular distribution of emitted particles, especially neutrons, depends on the deformation of the source nuclei sufficiently sensitively so as to determine the deformation from such measurements. The experimental data on the angular distribution of emitted neutrons, protons, and α-particles from aligned rotating deformed nuclei would be of great interest for these studies.

REFERENCES

[1] K. Pomorski, J. Richert, J. Bartel, K. Dietrich, *Nucl. Phys.* **A605**, 87 (1996).
[2] E. Strumberger, K. Dietrich, K. Pomorski, *Nucl. Phys.* **A529**, 522 (1991).
[3] V. Weisskopf, *Phys. Rev.* **52**, 295 (1937).
[4] H. Kramers, *Physica* **7**, 284 (1940).
[5] B. Nerlo-Pomorska, K. Pomorski, *Z. Phys.* **A 348**, 169 (1994).

[6] M. Gonin, L. Cooke, K. Hagel, Y. Lou, J.B. Natowitz, R.P. Schmitt, S. Shlomo, B. Srivastava, W. Turmel, H. Ustunomiya, R. Wada, G. Nardelli, G. Nebbia, G. Viesti, R. Zanon, B. Fornal, G. Prete, K. Niita, S. Hannuschke, P. Gonthier, B. Wilkins, *Phys. Rev.* **C42**, 2125 (1990).

[7] P. Grangé, H.C. Pauli, H.A. Weidenmüller, *Phys. Lett.* **B88**, 9 (1979); *Z. Phys.* **A296**, 107 (1980).

[8] D. Hilscher, H. Rossner, *Ann. Phys.* (FR) **17**, 471 (1992).

[9] W. Przystupa, K. Pomorski, *Nucl. Phys.* **A572**, 153 (1994).

[10] K. Pomorski, W. Przystupa, J. Richert, *Acta Phys. Pol.* **B25**, 751 (1994).