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# Formation of heavy and superheavy elements by reactions with massive nuclei

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**Abstract.** The effects of the entrance channel and shell structure on the experimental evaporation residues have been studied by analyzing the $^{32}$S + $^{182}$W, $^{48}$Ti + $^{166}$Er and $^{60}$Ni + $^{154}$Sm reactions leading to $^{214}$Th$^{*}$; the $^{40}$Ar + $^{181}$Ta reaction leading to $^{221}$Pa$^{*}$; the $^{48}$Ca + $^{243}$Am, $^{248}$Cm, $^{249}$Cf reactions leading to the $^{291}$115, $^{296}$116 and $^{297}$118 superheavy compound nuclei, respectively. The fusion mechanism and the formation of evaporation residues of heavy and superheavy nuclei have been studied. In calculations of the excitation functions for capture, fusion and evaporation residues we used such characteristics as mass asymmetry of nuclei in the entrance channel, binding energies and shape of colliding nuclei, potential energy surface, driving potential, partial-fusion cross-sections and survival probability of the compound nucleus, $\Gamma_{\mathrm{n}}/\Gamma_{\mathrm{f}}$ ratio at each step along the de-excitation cascade of the compound nucleus. The calculations have allowed us to make useful conclusions about the mechanism of the fusion-fission process, which is in competition with the quasifission process, and the production of the evaporation residues.

**PACS.** 25.70.Gh Compound nucleus – 25.70.-z Low and intermediate energy heavy-ion reactions – 27.80.+w $190 \leq A \leq 219$ – 27.90.+b $A \geq 220$

## 1 Introduction

In this paper we analyze the importance of the entrance channel effect on the fusion-fission reaction mechanism in collisions of massive nuclei by comparing the excitation functions of evaporation residues (ER) measured for different mass asymmetry reactions. Often the excitation functions of evaporation residues, measured in various reactions leading to the same compound nucleus (CN), differ not only by the position of the maximum but also by the value of their maxima. The study of characteristics of nuclei and the fusion-fission process which are responsible for such a difference in the evaporation residue cross-sections is necessary for finding the optimal conditions for the synthesis of new superheavy elements. The difference in the measured evaporation residues for the reactions leading to the same compound nuclei can be explained by the difference in the excitation functions of the fusion and survival probability of the excited compound nucleus. A decrease in the fusion cross-sections is connected with an increase in the contribution of the quasifission process. Quasifission reactions are binary processes which exhibit some of the characteristics of fusion-fission events, such as the full relaxation of the relative kinetic energy and considerable transfer of mass between the two fragments. The basic difference between the fusion-fission and quasifission processes is that the compound-nucleus formation is not achieved in the latter mechanism. In quasifission reactions, a dinuclear system, which is formed at the capture stage of heavy-ion collisions, can evolve over the potential energy surface before reaching mass symmetry or decay by way of overcoming the quasifission barrier. The latter decreases usually with an increase in the mass symmetry. Quasifission can be thought of as a bridge between deep inelastic scattering (in which the relative kinetic energy

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