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Role of charged particle emission on the evaporation residue formation in the ^{82}Se+^{138}Ba reaction leading to the ^{220}Th compound nucleus

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Abstract

We present detailed results of a theoretical investigation on the production of evaporation residue nuclei obtained in a heavy ion reaction when charged particles (proton and α-particle) are also emitted with the neutron evaporation along the deexcitation cascade of the formed compound nucleus. The almost mass symmetric ^{82}Se+^{138}Ba reaction has been studied since there are many experimental results on individual evaporation residue (ER) cross sections after few light particle emissions along the cascade of the ^{220}Th compound nucleus (CN) covering the wide 12–70 MeV excitation energy range. Our specific theoretical results on the ER cross sections for the ^{82}Se+^{138}Ba are in good agreement with the available experimental measurements, but our overall theoretical results concerning all possible relevant contributions of evaporation residues are several times greater than the ERs measured in experiment. The discrepancy could be due to the experimental difficulties in the identification of ER nuclei after the emission of multiple neutral and

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charged particles, nevertheless the analysis of ER data is very important to test the reliability of the model and to stress the importance on the investigation of ER nuclei also obtained after charged particle emissions.
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1. Introduction

The study of nuclear reactions continues to be of great interest in the scientific community to better understand the mechanism of the formation of final products in a nuclear collision. There are still relevant unclear discrepancies between experimental results as well as between different theoretical procedures [1]. Compound nucleus (CN) is formed if dinuclear system (DNS) [2] survives against quasifission which is dominant process in almost mass symmetric reactions. Compound nucleus stage can not be reached for angular momentum values $\ell > \ell_{max}$ (where ℓ_{max} is the maximum value of the angular momentum contributing to the DNS formation [1]) and the fast fission occurs producing binary fission-like fragments. At each step along the deexcitation cascade of the excited compound nucleus (CN) by emission of light particles in competition with the fission process, the evaporation residue (ER) nuclei can be formed [1,3–6] as reaction products. In this complex context two aspects of experimental uncertainties can be stressed: i) quasifission, fast fission and fusion–fission products might be overlapped; ii) some ER nuclei can not be detected and identified due to unavoidable limits of experimental setup causing difficulties in estimations of the cross sections by analysis of data [7,8]. In fact, in the case of the ^{82}Se+^{138}Ba reaction [7] the individual experimental ER contributions are in general well distinguishable, in some cases the ER channels are detectable as sum of two indistinguishable contributions; in other cases, other ER contributions that are relevant according to our estimations have not been measured.

In the analysis of experimental data there are unavoidable uncertainty on the identification and separation of the products that are formed in different channels of the reaction. Of course, even the theoretical models are not free from serious uncertainties of the obtained results due to the assumptions made in their formulation.

In this paper, we present the results of calculation of the individual ER excitation functions for the ^{82}Se+^{138}Ba almost mass symmetric reaction (characterized by a very low mass asymmetry parameter value $\eta = 0.255$) since it is possible to explore a wide region of excitation energy E^*_{CN} from 12 MeV (corresponding to the E^*_{thr} threshold energy for this entrance channel leading to the ^{220}Th CN formation) up to 70 MeV of excitation energy of CN, when the emission of the charged particles (proton and α) are also considered together with emission of neutrons. Therefore, the study of the ^{82}Se+^{138}Ba reaction remains a very useful opportunity to analyze the ER formation from lower excitation energies of CN. Moreover, the theoretical study of the ^{82}Se+^{138}Ba reaction benefits of the large set of experimental data [7] available for the individual excitation function of evaporation residue which can be compared with our theoretical results and discussed.

This large set of experimental data is a good opportunity to look for the necessary improvements in the experimental and theoretical investigations on the formation of ER nuclei also taking into account the various combinations of charged particle emissions (α and proton). In this context, it is also possible to obtain useful information on the ratio between the total evaporation residue cross section (charged and neutral particle emissions) and the one produced by neutron emissions only [9] at different values of E^*_{CN}.

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