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Production of ^{100}Sn in fusion reactions via cluster emission channels

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Abstract

The possibilities of production of the doubly magic nucleus ^{100}Sn in complete fusion and quasifission reactions with stable and radioactive ion beams are investigated within a dinuclear system model. The excitation functions for production of the exotic nuclei $^{100-103}$Sn via cluster emission channels are predicted for future experiments.

1 Introduction

^{100}Sn can be produced both in light particle and the cluster emission channels in fusion reactions. In Ref. [1], these possibilities were studied by measuring the production cross sections of very neutron-deficient isotopes of nuclei near ^{100}Sn in the reactions ^{58}Ni+^{50}Cr and ^{58}Ni+^{58}Ni. In these reactions both the evaporation and the cluster emission channels lead to similar production cross sections of exotic nuclei near ^{100}Sn. Because the probability of cluster emission increases with decreasing N/Z ratio of the compound nucleus (CN) [2], the cluster emission channels might become more important in the reactions with neutron-deficient radioactive ion beams. For instance, to produce ^{100}Sn in the ^{12,14}C emission channels, one can employ the reactions leading to the CN ^{112}Ba or ^{114}Ba. In the present work, the excitation functions for production of the exotic nuclei $^{100-103}$Sn in ^{12}Cxn emission channels in the fusion and quasifission reactions are predicted. Our calculations are based on the dinuclear system (DNS) model [2,3]. The DNS model was successfully applied for the description of charge and mass distributions of products of the fusion and quasifission reactions. The model was able to reproduce the absolute cross sections for individual isotopes within a factor of 2-3 in the considered reactions so far [2, 3].

2 Model

Here, we briefly present the main ingredients of the model and the more details can be found in Refs. [2,3]. DNS model describes an evolution of the charge and mass asymmetry degrees of freedom, which are defined here by the charge and mass (neutron) numbers Z_1 and A_1 (N_1) of light nucleus of the DNS, and relative distance R coordinate. According to the model, there are nucleon drift and nucleon diffusion between the DNS nuclei, which lead to the formation of excited CN and DNS configurations (DNS with different Z_1 and A_1) with probabilities depending on the potential energy surface and temperature of the system.

The cross section of the residual nucleus with certain mass number A and charge number Z is given as

$$\sigma_{Z,A}(E_{\text{c.m.}}) = \sum_{J=0}^{J_{max}} \sigma_{Z,A}(E_{\text{c.m.}}, J) = \sum_{J=0}^{J_{max}} \sigma_{cap}(E_{\text{c.m.}}, J) W_{Z,A}^{sur}(E_{\text{c.m.}}, J), \quad (1)$$

where σ_{cap} is the partial capture cross section which is calculated using the Hill-Wheeler formula. The probability for the production of certain residual nucleus (Z,A) from the excited entrance channel DNS in a distinct decay channel is described by $W_{Z,A}^{sur}(E_{\text{c.m.}}, J)$. To calculate $W_{Z,A}^{sur}(E_{\text{c.m.}}, J)$, one has to find the formation-emission probability $W_{Z_1,A_1}(E_{\text{c.m.}}, J)$ of a certain light particle or cluster (Z_1,A_1) from the excited system [2]. Formation probabilities and decay barriers are calculated using the double folding nucleus-nucleus potential with Skyrme-type density dependent effective nucleon-nucleon forces [4]. Angular momentum dependence of barriers are determined from centrifugal component of potential energy of DNS and CN configurations.

3 Results

The difficulties of the production of ^{100}Sn in fusion-evaporation reactions are mainly related with the drastically small probability of neutron emission from neutron-deficient CN.

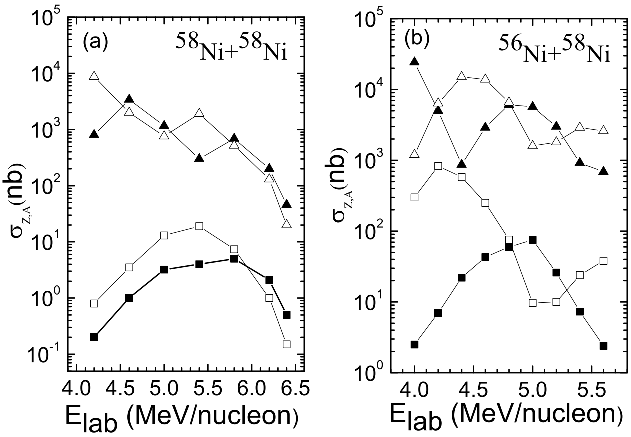

Figure 1: The calculated excitation functions for production of ^{100}Sn(■), ^{101}Sn (□), ^{102}Sn (▲), and ^{103}Sn (△) in cluster emission channels of the reactions ^{58}Ni + ^{58}Ni (a) and ^{56}Ni + ^{58}Ni (b). See the text for the details.

The production of ^{100}Sn in the fusion and quasifission reactions via cluster decay channels is mainly connected with the emission of ^{12,14}C due to the largest emission probability of carbon among heavy clusters. Hence, we consider the reactions ^{56,58}Ni + ^{58}Ni and ^{72}Kr + ^{40}Ca leading to the CN of barium. In Fig. 1, we present the calculated excitation functions for the production of $^{100-103}$Sn in the reactions ^{56,58}Ni + ^{58}Ni. It is seen that the excitation function becomes wider with increasing amount of evaporated particles. The excitation functions may have several maxima which correspond to different decay channels. The cluster decay channels are realized at low bombarding energies. With increasing bombarding energy, the light particle evaporation channels become dominant. For the reactions ^{58}Ni + ^{58}Ni at 5.6 - 5.8 MeV/nucleon [^{56}Ni + ^{58}Ni at 4.8 - 5.0 MeV/nucleon], the main decay channels leading to the production of ^{100}Sn are ^{12}C4n (40%) and ^{14}C2n (60%) [^{12}C2n (20%) and ^{14}C (80%)]. For the reactions ^{58}Ni + ^{58}Ni and ^{56}Ni + ^{58}Ni, the maximum production cross sections are about 5 and 75 nb, respectively.

For the ^{72}Kr + ^{40}Ca reaction with the radioactive beam, we present the excitation functions for production of exotic nuclei $^{100-103}$Sn (Fig.2). One can observe that the excitation function for ^{100}Sn has two maxima at energies 4.0 and 4.8 MeV/nucleon which correspond to the decay channels ^{12}C and 3α, respectively. The maximum production cross sections corresponding to the emission channels ^{12}C and 3α are 1 μb and 130 nb, respectively.

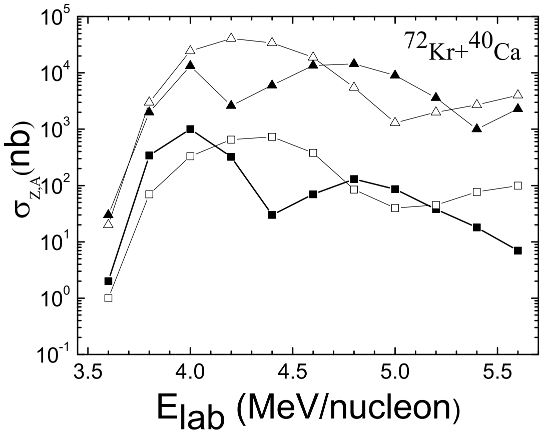

Figure 2: The same as in Fig. 5, but for the ^{72}Kr + ^{40}Ca reaction.

In conclusion, we have presented the DNS model predictions for the excitation functions for production of exotic nuclei $^{100-103}$Sn in the reactions ^{58,56}Ni + ^{58}Ni and ^{72}Kr + ^{40}Ca. The predicted maximum value of production cross section for ^{100}Sn in cluster emission channels are 5nb and 1 μb for the reactions with stable and radioactive ion beams, respectively.

Acknowledgements

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