Possibility to produce element 120 in the $^{54}Cr + ^{248}Cm$ hot fusion reaction

Zu-Hua Liu[1] and Jing-Dong Bao[2,3]

[1]*China Institute of Atomic Energy, Beijing 102413, People's Republic of China*

[2]*Department of Physics, Beijing Normal University, Beijing 100875, People's Republic of China*

[3]*Center of Theoretical Nuclear Physics, National Laboratory of Heavy Ion Accelerator, Lanzhou 730000, People's Republic of China*

(Received 27 October 2012; revised manuscript received 12 January 2013; published 12 March 2013)

Synthesis of element 120 in the ^{249}Cf(^{50}Ti,xn)$^{299-x}$120 and ^{248}Cm(^{54}Cr,xn)$^{302-x}$120 fusion evaporation reactions has been evaluated by means of a modified fusion by diffusion model. It is found that the fusion probability of the system $^{54}Cr + ^{248}Cm$ is two times smaller than that of $^{50}Ti + ^{249}Cf$. On the other hand, the survival probability of the former is obviously greater than that of the latter. As a result, the loss in the fusion probability of the $^{54}Cr + ^{248}Cm$ reaction is compensated by its gain in survival probability. The calculated maximum evaporation residue cross sections in the ^{249}Cf(^{50}Ti,3n)^{296}120 and ^{248}Cm(^{54}Cr,4n)^{298}120 reactions are quite close: 0.034 and 0.024 pb, respectively. Besides, as compared to the system $^{50}Ti + ^{249}Cf$, the $^{54}Cr + ^{248}Cm$ combination has two advantages. First, ^{248}Cm is much easier accumulate a sufficient amount for the target material than ^{249}Cf. Second, the isotope ^{298}120 has 178 neutrons, two neutrons more than the isotope ^{296}120. Therefore, the $^{54}Cr + ^{248}Cm$ combination should be one of most favorable candidates to produce superheavy element 120.

DOI: 10.1103/PhysRevC.87.034616 PACS number(s): 24.10.−i, 24.60.−k, 25.70.Jj, 27.90.+b

I. INTRODUCTION

Superheavy elements (SHEs) with $Z = 112$–118 have been synthesized [1–4] by employing ^{48}Ca-induced reactions with actinide targets of U-Cf within recent decades. A notable trend in the production of SHE with such reactions is that the cross sections maintain values of a few picobarns; even for the heaviest element 118, its production cross section is still at about 1 pb. This experimental observation may be in accordance with predictions of the relativistic and nonrelativistic mean field models [5]; i.e., the center of the "island of stability" locates at $Z = 120$–126 and $N = 184$. However, the macro-microscopic nuclear model [6,7] predicts the magic shell closure at $Z = 114$ and $N = 184$. Therefore, synthesis of new SHE with $Z \geqslant 120$ is of great interest theoretically.

Zagrebaev *et al.* [8] have made a comprehensive discussion on nuclear reactions leading to the formation of new SHE and isotopes, including two reaction systems $^{50}Ti + ^{249}Cf$ and $^{54}Cr + ^{248}Cm$. They suggest that as a first step towards elements $Z \geqslant 120$ the reaction $^{50}Ti + ^{249}Cf$ could be used to synthesize SHE 120, and then go on to synthesize elements 122 and 124 using the chromium and iron beams at available experimental setups if an increase of beam intensity and detection efficiency is achieved. In addition, we also have made an evaluation of the synthesis of SHE 120 in terms of the $^{50}Ti + ^{249-252}Cf$ fusion evaporation reactions [9].

In this work, we concentrate our attention on the reactions ^{249}Cf(^{50}Ti,xn)$^{299-x}$120 and ^{248}Cm(^{54}Cr,xn)$^{302-x}$120 and specify why the system $^{54}Cr + ^{248}Cm$ is one of the most favorable reaction combinations for synthesis of element 120. Generally speaking, asymmetric systems are more favorable in the SHE synthesis because fusion probability strongly decreases with increasing production of the charge numbers of projectile and target nuclei, $Z_1 Z_2$. However, since the absolute value of evaporation residue (ER) cross sections are dominated by the production of fusion and survival probabilities, in some cases the loss in the fusion probability for more symmetric system may be compensated by the gain in the survival probability. $^{54}Cr + ^{248}Cm$ is just such a reaction system. In Ref. [10], we have made a detailed analysis about the effects of the neutron binding energy and shell correction on the ER cross section and found that if $A_{\max}$ is the mass number of nucleus at which the absolute value of shell correction energy $\Delta_{\rm sh}^{\rm gs}$ reaches maximum, the most favorable fusion evaporation reactions in 3n and 4n channels may take place, respectively, with the reaction systems of one and two mass numbers of the compound nucleus (CN) greater than $A_{\max}$. As shown below, the projectile and target combination of $^{54}Cr + ^{248}Cm$ is nearly the case. In this connection, the reaction ^{248}Cm(^{54}Cr,xn)$^{302-x}$120 should be favorable.

II. MODEL AND RESULTS

The cross section of a superheavy nucleus produced in a heavy ion fusion-evaporation reaction can be written as

$$\sigma_{\rm ER}(E_{\rm c.m.}) = \pi \lambda^2 \sum_{l=0}^{\infty} (2l+1) P_{\rm capt}(E_{\rm c.m.}, l) \times P_{\rm fus}(E_{\rm c.m.}, l) P_{xn}(E_{\rm c.m.}, l), \qquad (1)$$

where $P_{\rm capt}$ is the capture probability in the entrance channel. We calculate $P_{\rm capt}$ by means of a semiphenomenological barrier distribution function method proposed by Zagrebaev *et al.* [11,12]. $P_{\rm fus}$ defines the probability that the system will go from the configuration of two nuclei in contact into the configuration of the CN. Finally, P_{xn} represents the survival probability of the excited compound nucleus after evaporation of x neutrons in the cooling process.

After contact, a rapid growth of the neck brings the reaction system from fusion valley into asymmetric fission valley. In this evolution process, the geometrical shape of the system is parameterized in terms of two spheres with radii R_1 and R_2 smoothly connected by a hyperboloidal neck. Three variables may be defined for a given shape: elongation, mass asymmetry, and neck size (n). Instead of elongation, we use s, namely, the separation between the surfaces of the approaching nuclei. In our previous work [13], we have shown that nucleon flow between the asymmetric reaction partners in the early stage of fusion process plays an important role in the formation of superheavy nuclei in the cold fusion reactions. For the hot fusion reactions, the influence of nucleon flow in the fusion probability is under investigation by means of the coupled Langevin equations in the three-dimensional collective space of neck, radial, and asymmetric degrees of freedom. Our primary results indicate that as far as the fusion probability is concerned, the drift and diffusion in the asymmetric degree of freedom play counterbalanced roles, and hence the effect of nucleon flow on the ER cross section is very limited in the hot fusion reactions. Besides, Światecki *et al.* [14,15] made a detailed explanation about the assumption that the subsequent diffusion continues to take place at fixed asymmetry in the "fusion by diffusion" (FBD) model. They pointed out that for very heavy systems, the energy of the macroscopic saddle in the asymmetric fission valley as calculated with their parametrization is expected to differ only slightly from the energy of the symmetric saddle point [15]. In the following, we assume that the neutron-proton equilibrium is achieved at contact point and the mass asymmetry is fixed thereafter.

The dynamic evolution from dinucleus (in the fusion valley) to mononucleus (in the asymmetric fission valley) is described by means of a two-dimensional coupled Langevin equation

$$\begin{aligned}\frac{dq_i}{dt} &= \mu_{ij} p_j,\\ \frac{dp_i}{dt} &= -\frac{1}{2} p_j p_k \frac{\partial \mu_{jk}}{\partial q_i} - \frac{\partial V(q)}{\partial q_i} - \gamma_{ij}\mu_{jk} p_k + \theta_{ij}\xi_j(t),\end{aligned} \tag{2}$$

where $q_i \equiv s, n$ stand for the collective coordinates, p_i are the conjugate momenta, $V(q)$ is the nuclear deformation potential energy calculated in framework of the finite-range liquid drop model [16,17], μ_{ij} ($i, j \equiv s, n$, same for the other quantities below) denotes the inverse matrix elements of the inertia tensor m_{ij}, and γ_{ij} is the friction tensor calculated with one-body dissipation model [18–22]. The normalized random variables ξ_j are assumed to be independent white noises. The strength θ_{ij} of the random force is given by $\theta_{ik}\theta_{kj} = T\gamma_{ij}$ with T the temperature of the heat bath. The inertia tensor m_{ij} was evaluated under the Werner-Wheeler approximation [23,24] for incompressible and irrotational flow.

The initial conditions for the radial and neck motions are defined in Refs. [18,25] except for the radial friction form factor in the surface friction model [26–28]. In order to keep the continuity of kinetic energy dissipation at the contact point, in the present work we use the radial friction for the separated nuclei with the Woods-Saxon form factor [29],

$$\gamma_R^{\text{surface}} = \gamma_R^0 (1 + e^{\zeta})^{-1}, \tag{3}$$

with $\gamma_R^0 = 40 \times 10^{-22}$ MeV s fm^{-2}, $\zeta = (s - \xi_R)/a_R$, $\xi_R = 2.0$ fm, and $a_R = 0.6$ fm. Similarly to the criterion suggested by Światecki [30], we define $n = \sqrt{0.5}R_i$ with $R_i = \min(R_1, R_2)$ to be the boundary between the dinuclear and mononuclear regimes. By solving these dynamic equations the probability distributions of radial degree of freedom at the injection point s_{inj} in the asymmetric fission valley are obtained. As an example, the resultant distributions $f(s_{\text{inj}})$ are plotted in Fig. 1 for the two systems at the CN excitation energy $E^* = 40$ MeV.

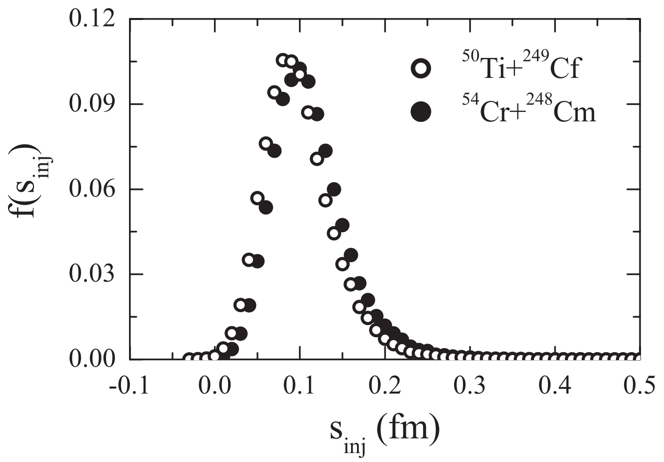

FIG. 1. Probability distributions of s_{inj} calculated with the coupled Langevin equations for the systems $^{50}\text{Ti} + {}^{249}\text{Cf}$ and $^{54}\text{Cr} + {}^{248}\text{Cm}$ at the CN excitation energy $E^* = 40$ MeV.

We use a modified FBD model [18,31] to evaluate the CN formation probability P_{fus},

$$P_{\text{fus}}(E_{\text{c.m.}}, l) = \frac{1}{2}\int \text{erfc}\left(\sqrt{B(s_{\text{inj}}, l)/T}\right) f(s_{\text{inj}}) ds_{\text{inj}}. \tag{4}$$

Here T is the temperature of the fusing system, which we take as the mean value of the initial temperature at injection point T_{inj} and the temperature at the top of the saddle point T_{sd}. $B(s_{\text{inj}}, l)$ is the barrier height measured from the injection point, which consists of the macroscopic deformation energy $\Delta E(s_{\text{inj}}, l = 0)$ and rotational energy $\Delta E^{\text{rot}}(s_{\text{inj}}, l)$ in the l-dependent FBD model [31]. The macroscopic deformation energy along the asymmetric fission valley is calculated using the refined algebraic expressions [31]. The corresponding values of the rotational energy at the injection point and at the symmetric saddle point are calculated with moments of inertial specified in Ref. [31].

Figure 2 shows the fusion probability as a function of angular momentum for the systems $^{50}\text{Ti} + {}^{249}\text{Cf}$ and $^{54}\text{Cr} + {}^{248}\text{Cm}$ at the CN excitation energy $E^* = 40$ MeV. It is found that the fusion probability of the system $^{50}\text{Ti} + {}^{249}\text{Cf}$ is about two times larger than that of $^{54}\text{Cr} + {}^{248}\text{Cm}$.

The survival probability P_{xn} was calculated with the convenient method; for details see Refs. [10,32,33]. The essential ingredient in the formulism is the ratio of the partial widths of neutron emission (Γ_n) and fission (Γ_f) for the nucleus after the emission of k neutrons:

$$\begin{aligned}\frac{\Gamma_n}{\Gamma_f}(E_k^*, l_k) &= \frac{4A^{2/3} a_f U_n^{\max}(k)}{K_0 a_n \left[2\sqrt{a_f U_f^{\max}(k)} - 1\right]}\\ &\quad \times \exp\left[2\sqrt{a_n U_n^{\max}(k)} - 2\sqrt{a_f U_f^{\max}(k)}\right],\end{aligned} \tag{5}$$

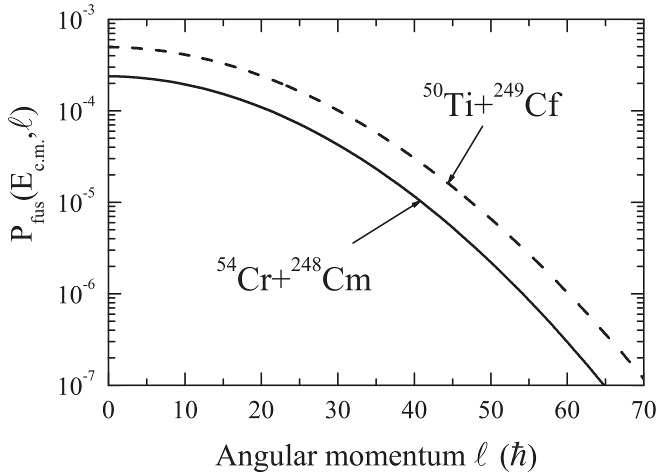

FIG. 2. Fusion probability as a function of angular momentum for the systems $^{50}\mathrm{Ti} + ^{249}\mathrm{Cf}$ and $^{54}\mathrm{Cr} + ^{248}\mathrm{Cm}$ at the CN excitation energy $E^* = 40$ MeV.

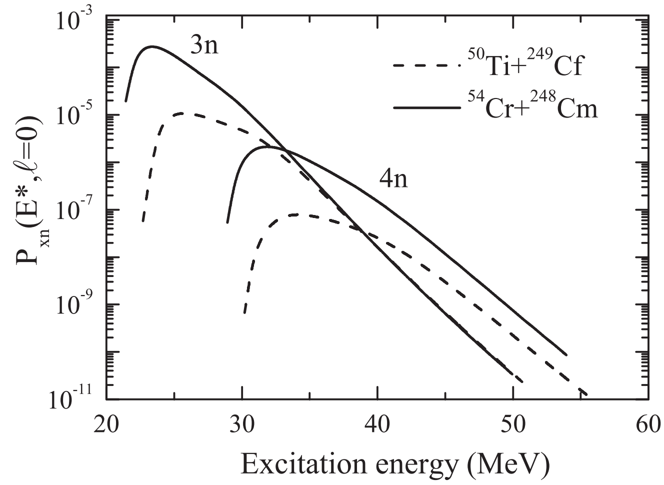

FIG. 3. A comparison of the survival probabilities $P_{xn}(E^*, l = 0)$ of the $3n$ and $4n$ evaporation channels between the systems $^{50}\mathrm{Ti} + ^{249}\mathrm{Cf}$ (dashed lines) and $^{54}\mathrm{Cr} + ^{248}\mathrm{Cm}$ (solid lines).

where A is the mass number of nucleus considered, $K_0 = \hbar^2/[2m_n r_0^2] \simeq 9.8$ MeV with m_n and r_0 are the neutron mass and nuclear radius, and a_n and a_f are the level density parameters of the daughter nucleus and the fissioning nucleus at the ground and saddle configurations, respectively. The $U_n^{\max}(k)$ and $U_f^{\max}(k)$ [33] denote the upper limit of the thermal excitation energies of the $(k+1)$th daughter nucleus in the ground state and nucleus at the saddle point after the emission of k neutrons. In the calculations of these excitation energies, data of the microscopic shell correction $\Delta_{\mathrm{sh}}^{\mathrm{gs}}$ in the ground state and the neutron separation energy are taken from Ref. [6], and the macroscopic deformation energies B_{LD} are set to be zero [33,34]. The shape-dependent level density parameter is given by the following expression [15]:

$$\tilde{a} = 0.076A + 0.180A^{2/3}F(\alpha) + 0.157A^{1/3}G(\alpha)\mathrm{MeV}^{-1}, \tag{6}$$

where the deformation of the nucleus is defined by the parameter $\alpha = (R_{\max} - R)/R$, where $R_{\max}$ is the semimajor axis of the nucleus with its radius R before deformation. The functions F and G are given in Ref. [15]. The smooth value of the level density parameter $\tilde{a}$ is modified due to shell effects according to the formula [33,35]

$$a = \tilde{a}\left\{1 + \frac{\Delta_{\mathrm{sh}}}{U}[1 - \exp(-U/E_D)]\right\}, \tag{7}$$

where E_D is the damping parameter describing the decrease of the influence of the shell effects on the energy level density with increasing excitation energy U of the nucleus. In this work, $E_D = 18.5$ MeV [33,36] is used. Siwek-Wilczyńska and Skwira [33] presented systematics of the shell corrections at saddle point $\Delta_{\mathrm{sh}}^{\mathrm{sd}}$ deduced from experimental fission excitation functions for a wide range of nuclei of $88 \leqslant Z \leqslant 100$. Their systematics show that the values of $\Delta_{\mathrm{sh}}^{\mathrm{sd}}$ are close to zero for the nuclei with $Z \geqslant 100$. Therefore, in the range of superheavy nuclei, the level density parameters a_f can be safely assumed to be independent of the excitation energy of the nucleus considered. On the other hand, the level density parameter a_n increases as the excitation energy increases due to the damping of the shell correction energy $\Delta_{\mathrm{sh}}^{\mathrm{gs}}$ of the ground state. Therefore, according to the formalism presented in Refs. [14,15,33], the damping of the shell effects directly influences the decay width of neutron emission Γ_n rather than the fission width Γ_f.

The survival probabilities P_{xn} as a function of CN excitation energy for the angular momentum $l = 0$ component are compared between the two systems in Fig. 3. It may be seen that the survival probability of $^{54}\mathrm{Cr} + ^{248}\mathrm{Cm}$ is obviously greater than that of $^{50}\mathrm{Ti} + ^{249}\mathrm{Cf}$.

Figure 4 displays the neutron binding energy B_n and the absolute value of shell correction $\Delta_{\mathrm{sh}}^{\mathrm{gs}}$ as a function of nucleus mass number A for SHE 120. Data are taken from Ref. [6]. The mass number corresponding the maximum absolute value of shell correction energy, $A_{\max}$, is 299 for this element, while the CN mass numbers for the systems $^{50}\mathrm{Ti} + ^{249}\mathrm{Cf}$ and

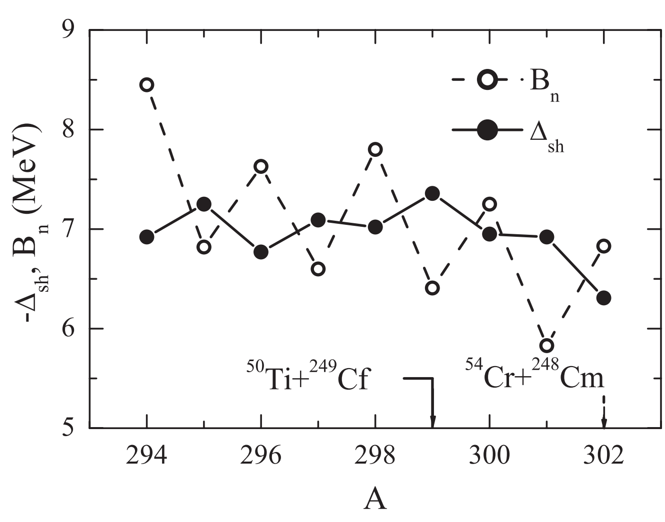

FIG. 4. The neutron binding energy (open circles) and the absolute value of shell correction (solid circles) as a function of nucleus mass number for the SHE 120. Data are taken from Ref. [6].

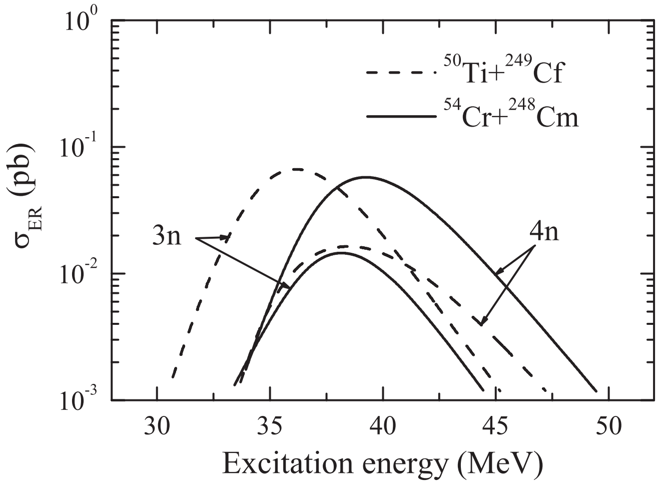

FIG. 5. Predicted evaporation residue cross sections for the $3n$- and $4n$-evaporation channels in the $^{50}Ti + ^{249}Cf$ (dashed lines) and $^{54}Cr + ^{248}Cm$ (solid lines) reactions.

$^{54}Cr + ^{248}Cm$ are 299 and 302, respectively. In Ref. [10] we have pointed out that a favorable choice of reaction system may obtain in terms of the exponential law, which is based on the approximate expression for the ratio between the neutron and fission disintegration widths due to Vandenbosch and Huizenga [32],

$$\frac{\Gamma_n}{\Gamma_f} = \frac{2TA^{2/3}}{k} \exp\left[(B_f - B_n)/T\right]. \quad (8)$$

Equation (8) means that the logarithm of Γ_n/Γ_f and the difference, d, between the fission barrier height and the neutron binding energy ($B_f - B_n$) have a simple relationship, i.e., a linear function. In the present approach, Γ_n/Γ_f depends on the mass difference (in units of the temperature) of the fission and neutron emission saddle points (see Fig. 9 in Ref. [15]). Correspondingly, the d value for the emission of k neutrons [10] is

$$d = \sum_{i=1}^{k} \left\{\left[B_{\rm LD} - \Delta_{\rm sh}^{\rm gs} + \Delta_p - B_n\right]_{i-1} - \left[\Delta_p - \Delta_{\rm sh}^{\rm gs}(1 - \exp(-U/E_D))\right]_i\right\}/T_{i-1}. \quad (9)$$

Here the suffixes in the sum of the first and second terms represent the values taken in the $(i-1)$th and its daughter nuclei, respectively. T_{i-1} is the corresponding nuclear temperature. The initial compound nucleus is indexed as $i = 0$. We find that the d values of the $3n$ evaporation channel are -15.10 and -14.46 for the systems $^{50}Ti + ^{249}Cf$ and $^{54}Cr + ^{248}Cm$. Correspondingly, for $4n$ channel they are -19.77 and -18.62, respectively. The larger d values for the system $^{54}Cr + ^{248}Cm$ basically bring about its larger ER survival probabilities, as shown in Fig. 3.

With the model described above, we have evaluated the ER cross sections of the $^{50}Ti + ^{249}Cf$ and $^{54}Cr + ^{248}Cm$ fusion-evaporation reactions and compared the results in Fig. 5. We find that the maximum ER cross sections in the $^{249}Cf(^{50}Ti,3n)^{296}120$ and $^{248}Cm(^{54}Cr,4n)^{298}120$ reactions are quite similar; they are 0.034 pb and 0.024 pb, respectively.

III. COMPARISON AND DISCUSSION

In order to test the model predictions, we have calculated the ER cross sections of the $^{136}Xe + ^{136}Xe$ and $^{48}Ca + ^{249}U$ fusion reactions and compared them with the experimental data in Fig. 6. It may be seen from the figure that the model is basically in reasonable agreement with the experiments.

In Fig. 7, our results of the $^{249}Cf(^{50}Ti,xn)^{299-x}120$ and $^{248}Cm(^{54}Cr,xn)^{302-x}120$ reactions are compared with the predictions of the other groups [8,39]. For these two reactions, the results of our calculations are similar to those predicted by Zagrebaev and Greiner [8] except that our maximum ER cross section in the $4n$ channel of the $^{50}Ti + ^{249}Cf$ reaction is about two times smaller than their result. The differences between our results and those of Siwek-Wilczyńska *et al.* [39] are in orders of magnitude. We have noticed that the data of fission barrier height used are different. Siwek-Wilczyńska *et al.* [39] adopted the the fission barrier heights [40,41] based on the Warsaw macroscopic-microscopic model [42]. We used the the absolute value of the ground-state shell correction energy of Möller *et al.* [6] as the mass excess of fission saddle point relative to the ground state at zero temperature. The shell correction data of Möller *et al.* [6] have been extensively used up to date in the predictions of the ER cross sections of superheavy nuclei (e.g., the very recent work of Zagrebaev *et al.* [43]).

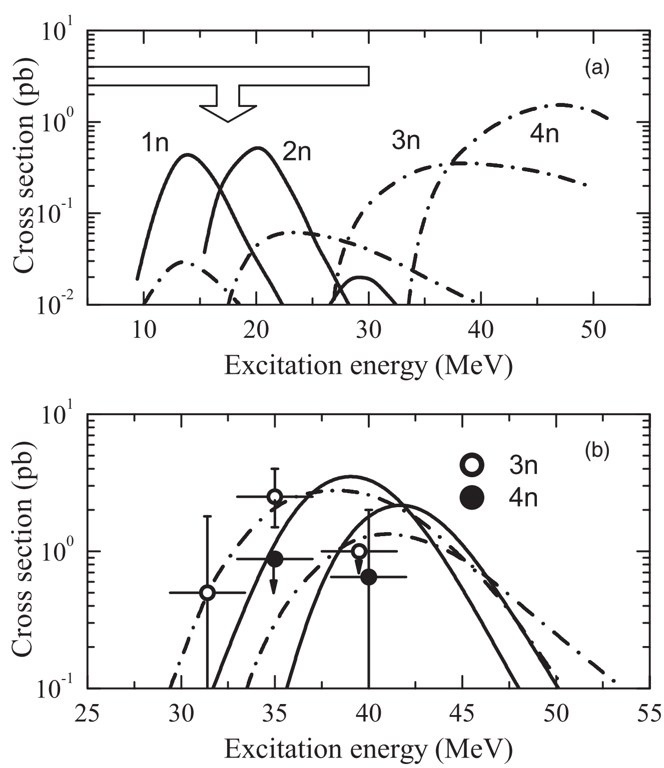

FIG. 6. Comparison between the theoretical predictions and experimental results for the $^{136}Xe + ^{136}Xe$ (a) and $^{48}Ca + ^{238}U$ (b) reactions. The solid lines are our model predictions. The dash-dotted lines are the predictions of Zagrebaev *et al.* [8,37]. The hollow bar in panel (a) shows the upper limit of the experimental ER cross sections in the $^{136}Xe + ^{136}Xe$ reaction [38]. The experimental data of the $^{48}Ca + ^{238}U$ reaction are taken from Ref. [2].

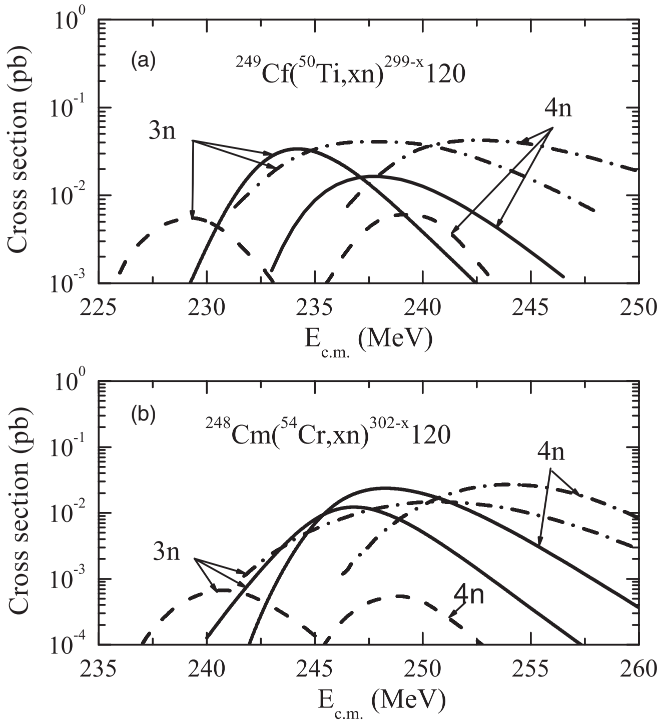

FIG. 7. Evaporation residue cross sections in the ^{50}Ti + ^{249}Cf (a) and ^{54}Cr + ^{248}Cm (b) fusion reactions. The solid lines show our predictions, whereas the dashed and dash-dotted lines are the predictions of Refs. [8,39], respectively.

In Fig. 8, we illustrate the recalculated ER cross sections for the ^{54}Cr + ^{248}Cm system based on the fission barrier of Warsaw and make a qualitative comparison with the results of Siwek-Wilczyńska *et al.* [39]. In the calculation, the fission barrier heights of odd-N nuclei are approximately evaluated from the adjacent even-even nuclei because the Warsaw's data of odd-odd and odd-even nuclei have not been published yet. It may be seen that the recalculated ER cross sections are much closer to those of Siwek-Wilczyńska *et al.* [39], thus clearly demonstrating the sensitivity of the SHE formation cross section to the fission barrier heights. Unfortunately, to date there is no clear-cut evidence about which nuclear structure model or approach provides a reliable prediction of the shell corrections in the superheavy nucleus region. In fact, the difference in the predictions of shell effects in the region under consideration with various microscopic models is not only its absolute values but also its trends with Z. Usually, nuclear models contain a number of parameters which are fixed for the best description of known nuclei. Therefore, the predictive power of the models may be limited for nuclei far from the well-studied region of nuclear chart. Actually, although great progress has been achieved in the synthesis of superheavy elements up to now, there is still an open question as to where the center of the "island of stability" is located. Theoretically, all advanced nuclear structure models [5–7,44] predict the existence of an "island of stability" around a new spherical doubly magic nucleus. However, there is no common prediction about this magic nucleus beyond ^{208}Pb among the different models [5–7,44]. Therefore, synthesis of superheavy elements with $Z \geqslant 120$ will provide fundamental knowledge of the next magic proton number and the relevant evidence about which prediction of the nuclear structure models should be more realistic. In this sense, the results of the present work should be conducive to the careful consideration on the experimental proposal aimed at synthesis of element 120.

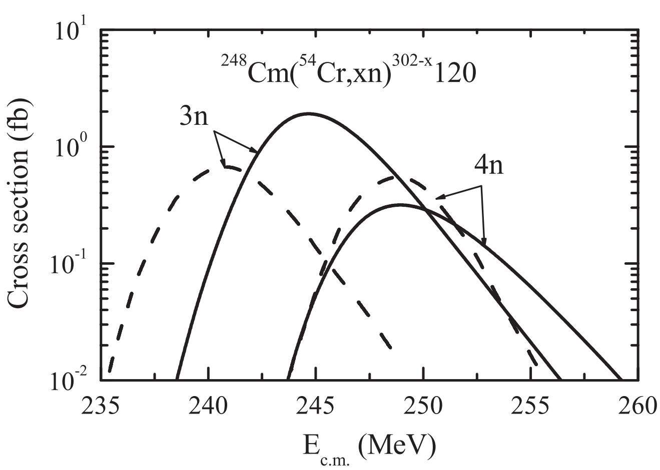

FIG. 8. Recalculated ER cross sections for the ^{54}Cr + ^{248}Cm system based on the even-even nucleus fission barrier of Warsaw (solid lines). The dashed lines are the predictions of Siwek-Wilczyńska *et al.* [39].

Nasirov *et al.* [45] also analyzed the ER cross sections for these two reaction systems using the dinuclear system (DNS) model. Their calculations show that the maximum values of ER excitation function in the 3n channel for the systems ^{50}Ti + ^{249}Cf and ^{54}Cr + ^{248}Cm are about 0.1 and 0.07 pb, respectively, but the yield of the 4n channel for the former reaction is lower (0.004 pb) in comparison with the one (0.01 pb) for the latter reaction. Recently, in terms of the DNS model, Wang *et al.* [46] have made an evaluation of the ER cross sections for the systems ^{50}Ti + ^{249}Cf and ^{54}Cr + ^{248}Cm, and claimed that the maximal ER cross sections are 0.05 and less than 0.01 pb, respectively. These different results evaluated with different models may reflect the fact that there is still large uncertainty in the predictions of the SHE formation cross sections nowadays. However, we emphasize here that one of the possible origins responsible for the difference in the predicted ER cross section may stem from the formula used in the survival probability. As mentioned above, the damping of the shell effects directly influences the decay width of neutron emission, Γ_n. In contrast, in a number of publications, the damping of the shell effects directly influences the decay width of fission Γ_f by using the formula

$$B_f = B_f(E^*_{\rm CN} = 0)\exp(-E^*_{\rm CN}/E_D), \quad (10)$$

where $E^*_{\rm CN}$ is the CN excitation energy. As pointed out by Światecki *et al.* [47], a conceptual error appears to be involved in such approach, which leads to formulas for the ratio of neutron to fission decay rates that no longer agree with those of the transition state theory [48].

IV. SUMMARY

We have calculated the evaporation residue cross sections for $3n$ and $4n$ evaporation channels in the ^{50}Ti + ^{249}Cf and ^{54}Cr + ^{248}Cm hot fusion reactions leading to formation of SHE 120 by means of the modified fusion by diffusion model. In the model, dynamic evolution from dinucleus to mononucleus is taken into account with the two-dimensional coupled Langevin equations. It is found that the fusion probability of the system ^{54}Cr + ^{248}Cm is two times smaller than that of ^{50}Ti + ^{249}Cf. On the other hand, the survival probability of the former is obviously greater than that of the latter one. As a result, the loss in the fusion probability of the ^{54}Cr + ^{248}Cm reaction is compensated by its gain in the survival probability. The calculated maximum ER cross sections in the ^{249}Cf(^{50}Ti,$3n$)^{296}120 and ^{248}Cm(^{54}Cr,$4n$)^{298}120 reactions are quite close; they are 0.034 and 0.024 pb, respectively. Therefore, ^{54}Cr + ^{248}Cm should be one of most favorable candidates to produce SHE 120. Moreover, as compared to the system ^{50}Ti + ^{249}Cf, the ^{54}Cr + ^{248}Cm combination has some advantages. First, ^{248}Cm is easier to accumulate in a sufficient amount as the target material than ^{249}Cf. Second, the isotope ^{298}120 has 178 neutrons, two neutrons richer than the isotope ^{296}120. In this sense, it is very attractive to produce SHE 120 in the ^{54}Cr + ^{248}Cm hot fusion reaction.

ACKNOWLEDGMENTS

This work was supported by the National Key Basic Research Program of China under Grant No. 2013CB834404 and the National Natural Science Foundation of China under Grant No. 11175021.

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