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Quasifission Products within the Dinuclear System Model

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Abstract.

Quasifission is the decay of a dinuclear system in two fragments. The dinuclear system consists of two touching nuclei which exchange nucleons. The quasifission is treated within a master equation which describes the evolution of the dinuclear system in charge and mass asymmetry and its decay along the internuclear distance. The calculated yields of quasifission products and their distributions in kinetic energy are in agreement with experimental data of hot fusion reactions with ^{48}Ca beams leading to superheavy elements.

1 Introduction

Experiments on quasifission were recently carried out in Dubna in connection with hot fusion reactions leading to superheavy elements [1]. Superheavy elements are produced in cold collisions of heavy ion projectiles with Pb (Bi) targets and in hot collisions with ^{48}Ca projectiles [2-4]. The evaporation residue cross sections for their production can be calculated with the dinuclear system model [5, 6]. The dinuclear system concept assumes two touching nuclei which keep their individuality and exchange nucleons [7]. It is formed in heavy ion collisions in the capture stage of the reaction after dissipation of the kinetic energy of the collision and then evolves in the mass and charge asymmetry coordinates towards fusion and quasifission. Quasifission means the decay of the dinuclear configuration without forming the compound nucleus. It bridges the gap between deep-inelastic collisions where the reaction partners get into contact without altering their average mass and charge and the complete fusion of the partners. Fusion and quasifission are competing processes which both give detailed information on the dynamics of the dinuclear system [8-10].

This article serves to explain the data of recent experiments [1] on quasifission. With master equations in the proton and neutron asymmetry degrees of freedom we calculate the time-development of the dinuclear configuration on its way to quasifission and fusion. The characteristics of mass, charge and kinetic energy distributions of quasifission products will be obtained and compared with available experimental data.

2 Master Equations for the Dynamics of Mass and Charge Transfer

The dinuclear system (DNS) model assumes a configuration of two touching nuclei which constitutes a nuclear molecule. The dynamics of the DNS is considered as a diffusion by nucleon transfer in the charge and mass asymmetry coordinates which are fixed by the charge and mass numbers $Z_P = Z$ and A_P of the light fragment (projectile) of the DNS. The corresponding numbers of the heavy fragment (target) are $Z_T = Z_{tot} - Z$ and $A_T = A_{tot} - A_P$, where Z_{tot} and A_{tot} are the total charge and mass numbers of the DNS, respectively. The dynamics of the DNS simultaneously evolves in Z and A_P by transfer of protons and neutrons and in R by its decay.

The starting point for the derivation of the master equations is the single-particle Hamiltonian of the DNS [11]:

$$H(\mathbf{R}) = \sum_{i=1}^{A_{tot}} \left(-\frac{\hbar^2}{2m}\Delta_i + U_P(\mathbf{r_i} - \mathbf{R}) + U_T(\mathbf{r_i}) \right). \quad (1)$$

Here, U_P and U_T are the single-particle potentials of the light and heavy nucleus, respectively. Using creation and anihilation operators we rewrite Eq. (1) in second quantization,

$$H = H_0 + V_{int}, \quad (2)$$

$$H_0 = \sum_P \epsilon_P a_P^+ a_P + \sum_T \epsilon_T a_T^+ a_T \quad (3)$$

$$V_{int} = \sum_{P,T} (g_{PT}(R_m) a_P^+ a_T + h.c.) \quad (4)$$

with $g_{PT}(R_m) = \frac{1}{2} < P|U_P + U_T|T >$ where R_m is the distance of the nuclei in the minimum of the internuclear potential. Since we assume a thermal equilibrium in the DNS we disregard the excitation of the light fragment by the heavy one and vice versa. Denoting the fragmentation by Z, $N = N_P$ and $Z_{tot} - Z$, $N_{tot} - N$, we introduce the unperturbed states of the DNS, $|Z, N, n>$, solving

$$H_0|Z,N,n>= E_n^{Z,N}|Z,N,n> \tag{5}$$

with the eigenvalues $E_n^{Z,N}$. Then a master equation for the probability $P_{Z,N}(n,t)$ to find the DNS in the state (Z,N,n) at time t can be formulated

$$\frac{d}{dt}P_{Z,N}(n,t) = \sum_{Z',N',n'} \lambda(Z,N,n|Z',N',n')[P_{Z',N'}(n',t) - P_{Z,N}(n,t)] - [\Lambda^{qf}_{Z,N}(n) + \Lambda^{fis}_{Z,N}(n)]P_{Z,N}(n,t). \tag{6}$$

The transition rate $\lambda(Z,N,n|Z',N',n') = \lambda(Z',N',n'|Z,N,n)$ can be calculated in time-dependent first order perturbation theory:

$$\lambda(Z,N,n|Z',N',n') = \frac{1}{\Delta t}|<Z,N,n|V_{int}|Z',N',n'>|^2 \times \frac{\sin^2[\Delta t(E_n^{Z,N} - E_{n'}^{Z',N'})/2\hbar]}{(E_n^{Z,N} - E_{n'}^{Z',N'})^2/4}, \tag{7}$$

where the time interval $\Delta t = 10^{-22}$ s is larger than the relaxation time of the mean field but considerably smaller than the reaction time. The quantities $\Lambda^{qf}_{Z,N}(n)$ and $\Lambda^{fis}_{Z,N}(n)$ are the rates for quasifission and for the fission of the heavy nucleus with $Z_{tot} - Z$ and $N_{tot} - N$ in the DNS, respectively.

Because of the single-particle character of the interaction energy (4), the transition rates (7) are only non-zero between states which differ by one particle-hole pair. In order to simplify the system of the differential equations, we assume that the DNS is in thermal equilibrium, and factorize $P_{Z,N}(n,t)$ in the form

$$P_{Z,N}(n,t) = P_{Z,N}(t)\Phi_{Z,N}(n,\Theta). \tag{8}$$

Here, $\Phi_{Z,N}(n,\Theta)$ is the probability for finding the DNS in the states n at a local temperature $\Theta(Z,N)$ and is normalized to unity. Using Fermi occupation numbers for the single-particle states as functions of $\Theta(Z,N)$ and summing over the DNS states n, we finally obtain the master equations used in the calculations:

$$\begin{aligned}\frac{d}{dt}P_{Z,N}(t) =& \Delta^{(-,0)}_{Z+1,N}\,P_{Z+1,N}(t) + \Delta^{(+,0)}_{Z-1,N}\,P_{Z-1,N}(t)\\ &+\Delta^{(0,-)}_{Z,N+1}\,P_{Z,N+1}(t) + \Delta^{(0,+)}_{Z,N-1}\,P_{Z,N-1}(t)\\ &-(\Delta^{(-,0)}_{Z,N} + \Delta^{(+,0)}_{Z,N} + \Delta^{(0,-)}_{Z,N}\\ &+\Delta^{(0,+)}_{Z,N} + \Lambda^{qf}_{Z,N} + \Lambda^{fis}_{Z,N})\,P_{Z,N}(t)\end{aligned} \tag{9}$$

with

$$\Delta^{(\pm,0)}_{Z,N}(\Theta) = \frac{1}{\Delta t}\sum_{P,T}^{Z} \mid g_{PT} \mid^2 n_{\substack{T\\P}}(\Theta)(1-n_{\substack{P\\T}}(\Theta))\frac{\sin^2[\Delta t(\epsilon_P-\epsilon_T)/2\hbar]}{(\epsilon_P-\epsilon_T)^2/4},$$

$$\Delta^{(0,\pm)}_{Z,N}(\Theta) = \frac{1}{\Delta t}\sum_{P,T}^{N} \mid g_{PT} \mid^2 n_{\substack{T\\P}}(\Theta)(1-n_{\substack{P\\T}}(\Theta))\frac{\sin^2[\Delta t(\epsilon_P-\epsilon_T)/2\hbar]}{(\epsilon_P-\epsilon_T)^2/4},$$

$$\Lambda^{qf}_{Z,N}(\Theta) = \sum_n \Lambda^{qf}_{Z,N}(n)\Phi_{Z,N}(n,\Theta),\ \Lambda^{fis}_{Z,N}(\Theta) = \sum_n \Lambda^{fis}_{Z,N}(n)\Phi_{Z,N}(n,\Theta).$$

This system of equations has to be solved with the initial condition $P_{Z,N}(0) = \delta_{Z,Z_i}\cdot\delta_{N,N_i}$. The rates for the transfer of a neutron or proton from the heavy nucleus to the light one ($\Delta^{(+,0)}_{Z,N}$, $\Delta^{(0,+)}_{Z,N}$) and in opposite direction ($\Delta^{(-,0)}_{Z,N}$, $\Delta^{(0,-)}_{Z,N}$) depend on the temperature-dependent Fermi occupation numbers of the single-particle states. We used single-particle states in spherical Woods-Saxon potentials with spin-orbit and Coulomb interactions. Also the rotation of the DNS is phenomenologically taken into account in the single-particle energies.

The decay rates of the DNS for quasifission depend on the height B_{qf} of the outer potential barrier. The value of B_{qf} is given with respect to the pocket in the nucleus-nucleus potential which is situated at the distance $R_m = R_P(1+\beta_P\sqrt{5/(4\pi)}) + R_T(1+\beta_T\sqrt{5/(4\pi)}) + 0.5$ fm. The barrier at $R_b = R_m + 1.5$ fm controls the quasifission process and is nearly independent of the angular momentum for $J < 70$ because the DNS has a large moment of inertia. The height of the barrier is about 4.5 MeV at $Z = 20$ and less than 0.5 MeV for $Z = Z_{tot}/2 \pm 10$.

The decay of the DNS in R can be treated with the one-dimensional Kramers rate [12-14]

$$\Lambda^{qf}_{Z,N}(\Theta) = \frac{\omega}{2\pi\omega^{B_{qf}}}\left(\sqrt{\left(\frac{\Gamma}{2\hbar}\right)^2 + (\omega^{B_{qf}})^2} - \frac{\Gamma}{2\hbar}\right) \times \exp\left(-\frac{B_{qf}(Z,N)}{\Theta(Z,N)}\right). \quad (10)$$

The temperature $\Theta(Z,N)$ is calculated with the Fermi-gas expression $\Theta = (E^*/a)^{1/2}$ with the excitation energy $E^*(Z,N)$ of the DNS and $a = A_{tot}/12\ \text{MeV}^{-1}$. For a nearly symmetric DNS we find about $\Theta = 1.5$ MeV. An inverted harmonic oscillator with the frequency $\omega^{B_{qf}}$ approximates the potential around the top of the quasifission barrier, and a harmonic oscillator with the frequency ω gives the potential at the pocket. We use constant values for these quantities: $\hbar\omega^{B_{qf}} = 1.0$ MeV and $\hbar\omega = 2$ MeV, and set the width $\Gamma = 2.8$ MeV in (10).

3 Charge and Mass Yields

The charge and mass yields for quasifission can be calculated by the expression

$$Y_{Z,N}(t_0) = \Lambda^{qf}_{Z,N} \int\limits_0^{t_0} P_{Z,N}(t)dt, \tag{11}$$

where $t_0 \approx (3-4)\cdot 10^{-20}$ s is the reaction time which is about ten times larger than the time of deep-inelastic collisions. This time is determined by solving the balance equation for the probabilities:

$$\sum_{Z,N}[\Lambda^{qf}_{Z,N} + \Lambda^{fis}_{Z_{tot}-Z,N_{tot}-N}] \int\limits_0^{t_0} P_{Z,N}(t)dt = 1 - P_{CN}. \tag{12}$$

Here, $P_{CN} = \sum_{Z<Z_{BG},N<N_{BG}} P_{Z,N}(t_0)$ is the probability for fusion, defined by the fraction of probability existing for $Z < Z_{BG}$ and $N < N_{BG}$ at time t_0, where Z_{BG} and N_{BG} determine the barrier B_{fus} for fusion in the asymmetry coordinates. The DNS with $Z < Z_{BG}$ evolves to the compound nucleus in a time of 10^{-21}s which is short compared with the decay time of the compound nucleus. The mass and charge yields of quasifission products are given as

$$Y(A_P) = \sum_Z Y_{Z,A_P-Z}(t_0), \qquad Y(Z_P) = \sum_N Y_{Z,N}(t_0). \tag{13}$$

The cross section for quasifission can be calculated as

$$\sigma_{qf}(E_{\rm c.m.}) \approx (1 - P_{CN}(E_{\rm c.m.}) - P_f(E_{\rm c.m.}))\sigma_{cap}(E_{\rm c.m.}) \tag{14}$$

with the capture cross section

$$\sigma_{cap}(E_{\rm c.m.}) = \frac{\pi\hbar^2}{2\mu E_{\rm c.m.}} J_{cap}(J_{cap}+1). \tag{15}$$

Here, $\hbar J_{cap} \le (2\mu R_b^2(E_{\rm c.m.} - V_b))^{1/2}$, and J_{cap} is smaller than the critical angular momentum J_{crit}. Trajectories with $J \ge J_{crit}$ contribute to deep-inelastic and quasi-elastic collisions. The fission probability of the heavier fragment is obtained by (see Eq. (12))

$$P_f = \sum_{Z,N} \Lambda^{fis}_{Z_{tot}-Z,N_{tot}-N} \int\limits_0^{t_0} P_{Z,N}(t)dt. \tag{16}$$

Reactions with $P_{CN} \ll 1$ and $P_f \ll 1$ have $\sigma_{qf} \approx \sigma_{cap}$. Partial cross sections for quasifission can also be calculated:

$$\sigma_{qf}(E_{\rm c.m.}, A_P) = Y(A_P)\sigma_{cap}(E_{\rm c.m.}). \tag{17}$$

4 Total Kinetic Energy Distribution

The average total kinetic energy (TKE) of the quasifission products and its dispersion depend strongly on the deformation of the fragments. For nearly symmetric dinuclear systems with $A = (A_P + A_T)/2 \pm 20$, we found deformations which are about 3-4 times larger than the deformations of the nuclei in their ground states. These large polarisations of the DNS nuclei have to be regarded to explain the experimental TKEs of the quasifission fragments.

We assume that the distribution of the fragments in charge, mass and deformation can be written as

$$\begin{aligned} W &= W(Z, N, \beta_P, \beta_T) \\ &= Y_{Z,N}(t_0) w_{\beta_P}(Z, N) w_{\beta_T}(Z_{tot} - Z, N_{tot} - N). \end{aligned} \quad (18)$$

The distributions of the deformations β_P and β_T are chosen as Gaussian distributions at fixed values of Z and N:

$$w_\beta(Z, N) = \frac{1}{\sqrt{2\pi\sigma_\beta^2}} \exp(-(\beta - <\beta>)^2/(2\sigma_\beta^2)), \quad (19)$$

where $\sigma_\beta^2 = (\hbar\omega_{vib})/(2C_{vib}) \cdot \coth(\hbar\omega_{vib}/(2k\Theta))$ with the frequency $\omega_{vib}(Z, N)$ and the stiffness parameter $C_{vib}(Z, N)$ of the quadrupole vibrations. The determination of these quantities from the experimental spectra is described in detail in Ref. [10]. Using the distribution W, we get the average TKE as a function of the mass number A_P of the light fragment:

$$< TKE(A_P) >= \frac{\int\int d\beta_P d\beta_T \sum\limits_{\substack{Z,N \\ Z+N=A_P}} TKE \cdot W}{\int\int d\beta_P d\beta_T \sum\limits_{\substack{Z,N \\ Z+N=A_P}} W}, \quad (20)$$

where we set $TKE = V_{nucl}(R_b) + V_{coul}(R_b)$ with the radius R_b at the position of the quasifission barrier. The variance of the TKE is

$$\begin{aligned} \sigma_{TKE}^2(A_P) \approx \sum_Z TKE^2|_{\substack{\beta_P=<\beta_P> \\ \beta_T=<\beta_T>}} \frac{Y_{Z,A_P-Z}(t_0)}{\sum\limits_Z Y_{Z,A_P-Z}(t_0)} - < TKE(A_P) >^2 \\ + (\sigma_{TKE}^{def}(A_P))_P^2 + (\sigma_{TKE}^{def}(A_P))_T^2 \end{aligned} \quad (21)$$

with $(j = P, T)$

$$(\sigma_{TKE}^{def}(A_P))_j^2 = \sum_Z \left(\frac{\partial TKE}{\partial \beta_j} \right)^2 \Bigg|_{\substack{\beta_P=<\beta_P> \\ \beta_T=<\beta_T>}} \frac{\sigma_{\beta_j}^2 Y_{Z,A_P-Z}(t_0)}{\sum\limits_Z Y_{Z,A_P-Z}(t_0)}. \quad (22)$$

5 Results for Hot Fusion Reactions

The elements 112, 114 and 116 were produced at the JINR in Dubna in reactions with ^{48}Ca projectiles incident on U, Pu and Cm targets, respectively [3]. The data for the mass yields and for the variances of the TKE of the fragments in these reactions were measured by Itkis *et al.* [1] in Dubna.

Figure 1 shows the calculated mass yield $Y(A_P)$ and the variance of the TKE of the fragments as functions of the mass number for the hot fusion reaction ^{48}Ca + ^{238}U $\rightarrow$ ^{286}112 in comparison with experimental data. The incident energy corresponds to an excitation energy of the compound nucleus of 33.4 MeV. The small oscillations in the experimental data are comparable with the accuracy of the measurements. Near the initial mass number A=48 the quasifission events overlap with the products of deep-inelastic collisions and were taken out in the experimental analysis since it is difficult to discriminate them from deep-inelastic events. The calculated peak near the initial mass number contains only quasifission events because the calculations disregard angular momenta larger

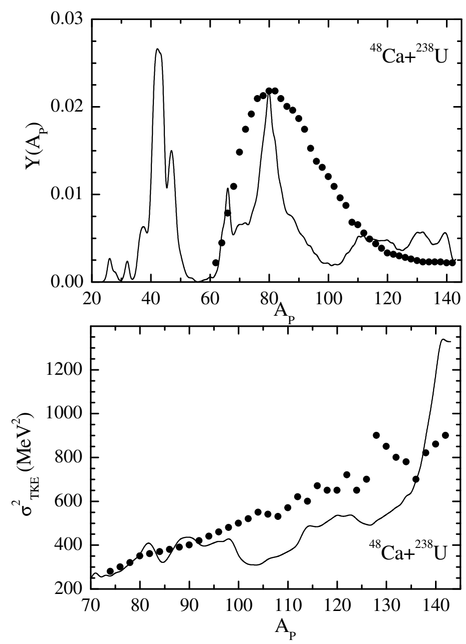

Figure 1. The calculated (solid lines) mass yield (upper part) and variance of the TKE (lower part) of the quasifission products as a function of mass number of the light fragment for the hot fusion reaction ^{48}Ca+^{238}U $\rightarrow^{286}$112 at a bombarding energy corresponding to an excitation energy of the compound nucleus of 33.4 MeV. The experimental data [1] are shown by solid points.

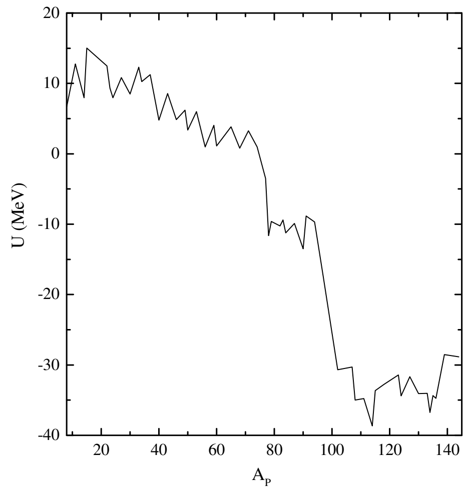

Figure 2. Calculated dependence of the potential energy of DNS as a function of mass number of the light fragment for the ^{48}Ca+^{238}U reaction at $J = 0$. The deformation parameters are taken from Ref. [15] for the nuclei of the DNS. The potential energy is minimized with respect to the N/Z-ratio ($A_P = Z + N$).

than the critical one which belong to deep inelastic and quasi-elastic collisions. Since the quasifission barrier is rather small in the entrance channel, the peak around the initial mass number is pronounced.

Maxima in the mass and charge yields arise due to minima in the driving potential $U(R_m, Z, N, \beta_P^{gs}, \beta_T^{gs}, J)$ which are caused by shell effects in the dinuclear system. Figure 2 shows the driving potential for J=0 for the collision ^{48}Ca + ^{238}U after minimization with respect to the ratio N/Z at each A_P. For $A_P > 48$, the maximum yield of the quasifission products appears around the nucleus ^{208}Pb for the heavy fragments ($A_P = 78$) where the driving potential has several minima. The height of the peak around $A_P = 80$ is 4.5 times larger than the height of the peaks in the symmetric mass region.

With our calculations we predict mass yields for light fragments with $A_P < 48$. Complementary to the heavier fragments with $A_P > 48$, the light fragments would give significant information about the dynamics of the dinuclear system on its way to the fused system. The yield of light products is known to be larger for higher beam energies. It would be a challenge for experimentalists to measure also this region of the mass yield.

The calculated data in the figures are related to the primary fragments before neutron emission. Therefore, the maxima and minima in the calculated functions $Y(A_P)$ and $\sigma^2_{TKE}(A_P)$ are more pronounced than those of the measured data where the neutron evaporation washes the structures out in these functions.

Table 1. The calculated average variance σ^2_{TKE} of the TKE for the nearly symmetric quasifission products with $A_{tot}/2 - 20 \leq A_P \leq A_{tot}/2$, fraction of the fusion-fission events with respect to the quasifission events in the mass region $A_{tot}/2 - 20 \leq A_P \leq A_{tot}/2$, and the calculated total number ($M_n^{tot-sym}$) of emitted neutrons for nearly symmetric quasifission splitting with $A_{tot}/2 - 20 \leq A_P \leq A_{tot}/2$. The reactions and the energies of corresponding compound nuclei are indicated.

Reactions	E^*_{CN} (MeV)	σ^2_{TKE} (MeV^2)	$P_{CN}/\sum_{A_P=A_{tot}/2-20}^{A_{tot}/2} Y(A_P)$	$M_n^{tot-sym}$
^{40}Ar+^{165}Ho	89	119	1.1	5.5
	120	143	0.7	7.3
^{48}Ca+^{244}Pu	34.8	805	1.4×10^{-2}	7.5
	50	893	1.1×10^{-1}	8.5
^{86}Kr+^{208}Pb	17	738	2.1×10^{-7}	4.8
	30	813	2.0×10^{-5}	7.0

Taking into account experimental uncertainties in the discrimination between the quasifission and fusion-fission (see Table 1), we obtained quite good agreement between the calculated and experimental data.

The minima in the dependence of σ^2_{TKE} on A_P in Figure 1 (and also in Figure 4) arise due to stiff nuclei in the DNS like Zr, Sn and Pb. The absolute height of the calculated σ^2_{TKE} agrees well with the experimental data.

In Figures 3 and 4 we show the results of calculations in comparison with experimental data for the collision of ^{48}Ca with ^{244}Pu and with ^{248}Cm at incident energies corresponding to an excitation of 42 and 37 MeV, respectively. As indicated by the solid and dashed curves in Figure 4, we only find a weak dependence of the results on the angular momentum, chosen as $J = 0$ and 70, respectively, because the DNS has a large moment of inertia.

Figure 5 depicts the contributions of the fluctuations of the transfer of nucleons and of the deformations to the variance of the TKE shown in Figure 4. This result demonstrates the importance of the fluctuations in the deformation for the calculation of σ^2_{TKE}. The contributions to the variance of TKE due to nucleon exchange come only into play for very asymmetric dinuclear systems.

Beside the calculation for hot fusion reactions we also carried out calculations of quasifission and TKE variances for reactions with a ^{58}Fe beam, for cold fusion reactions with Pb targets and for reactions with lighter nuclei, e.g. ^{40}Ar + ^{165}Ho (for details see Ref. [10]). In Table 1 we list calculated relative contributions of the fusion-fission process with respect to the quasifission and the calculated total numbers of emitted neutrons for nearly symmetric quasifission splitting for examples of various types of reactions. The contribution of fusion-fission is mainly determined by the fusion probability P_{CN} since the survival

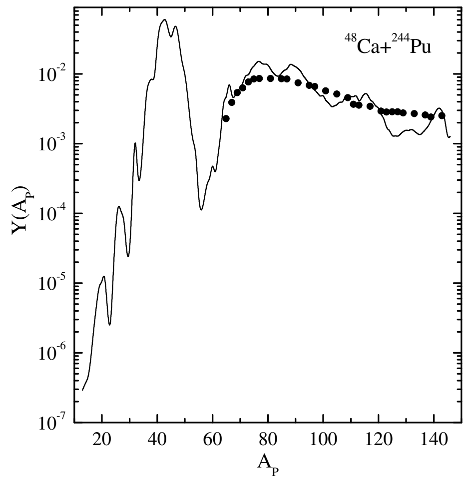

Figure 3. Mass yield of the quasifission products as a function of the mass number of the light fragment for the hot fusion reaction ^{48}Ca+^{244}Pu $\rightarrow^{292}$114 at a bombarding energy corresponding to an excitation energy of the compound nucleus of 42 MeV. The available experimental dat

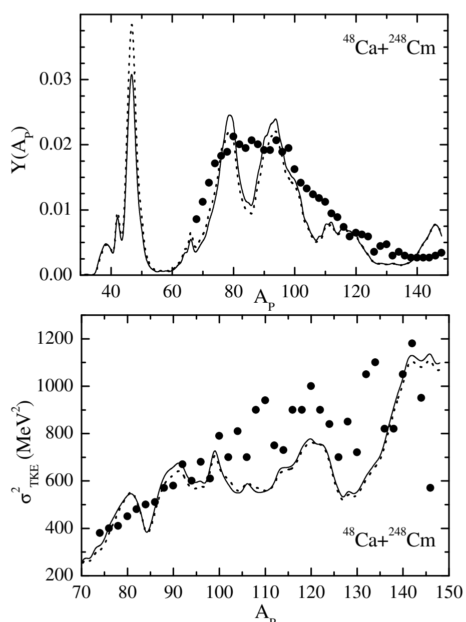

Figure 4. The same as in Fig. 1, but for the hot fusion reaction ^{48}Ca+^{248}Cm$\rightarrow^{296}$116 at the bombarding energy corresponding to an excitation energy of the compound nucleus of 37 MeV. The results calculated for $J = 0$ and 70 are presented by solid and dotted curves, respectively. The experimental data [1] are shown by solid points.

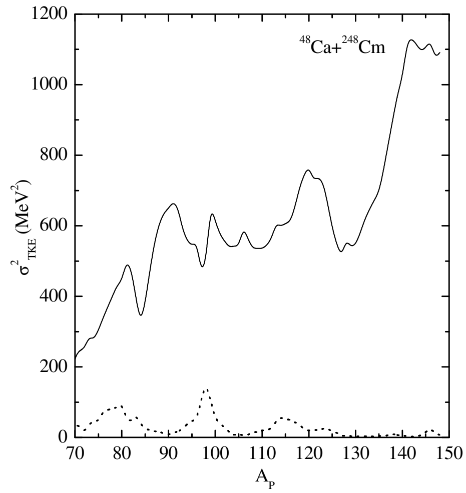

Figure 5. Contributions of the fluctuations in deformation (solid line) and of nucleon exchange (dotted line) to the variance of the TKE of quasifission products as a function of mass number of the light fragment for the hot fusion reaction ^{48}Ca+^{248}Cm at a bombarding energy corresponding to an excitation energy of the compound nucleus of 37 MeV.

probability of the excited compound nucleus is much less than unity. One recognizes that this contribution increases with incident energy, but remains small in the reactions considered. Therefore, the quasifission process mainly gives the yield of nearly symmetric products. For example, for the reaction ^{48}Ca ($E_{c.m.} = 193$ MeV) + ^{238}U (Figure 1) the calculated cross section of the yield of quasifission fragments with mass numbers $A_{tot}/2 \pm 20$ is about 4.5 mb at $J_{cap} = 25$ in good agreement with the measured value of about 5 mb.

6 Summary and Conclusions

The dinuclear system concept assumes two touching nuclei which can exchange nucleons by transfer. With this concept one describes the fusion to superheavy nuclei, the competing quasifission and nuclear structure phenomena related to cluster structures. The mass and charge transfers are difussion processes and can be described by master equations for the probabilities of the cluster configurations of the dinuclear systems. The quasifission is the decay of the dinuclear system with a decay rate determined by the Kramers formula.
The calculated quasifission yields and variances of total kinetic energies of quasifission fragments in hot fusion actinide-based reactions with ^{48}Ca and ^{58}Fe projectiles are in agreement with available experimental data. If the heavier reaction partner with $Z > 96$ goes to fission, this fission with a following fusion of

one fission fragment with the light nucleus of the DNS can be mixed with nearly symmetric quasifission. The total number of neutrons from pre- and post-decays accompanying the quasifission is well described in our model.

The quasifission process suppresses the complete fusion of heavy nuclei. Therefore, a consistent treatment of quasifission and fusion and a satisfying agreement between theory and experiment constitutes a critical test for the dynamics of these heavy ion reactions. A measurement of highly asymmetric quasifission products is needed to prove the evolution of the DNS to the compound nucleus in the mass asymmetry coordinate.

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