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THE ANALYSIS OF REACTIONS LEADING TO SYNTHESIS OF SUPERHEAVY ELEMENTS WITHIN THE DINUCLEAR SYSTEM CONCEPT

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Анализ реакций, приводящих к синтезу сверхтяжелых элементов, в рамках концепции двойной ядерной системы

Для анализа реакций полного слияния ядер, приводящих к синтезу сверхтяжелых элементов, была использована концепция двойной ядерной системы. Были рассчитаны оптимальная энергия возбуждения составных ядер и поперечные сечения получения в холодном методе синтеза тяжелых элементов в диапазоне $Z = 102 - 112$. Рассмотрена возможность получения нового элемента с магическим зарядом $Z = 114$ в реакциях холодного и горячего слияния.

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The Analysis of Reactions Leading to Synthesis of Superheavy Elements within the Dinuclear System Concept

The dinuclear system concept of complete fusion of nuclei has been applied to the analysis of superheavy elements synthesis. The optimal excitation energy of compound nuclei and production cross sections in the cold synthesis of heavy elements with charge $Z = 102 - 112$ have been calculated. The possibility of synthesising the element with magic number $Z = 114$ in cold and hot fusion reactions has been considered.

The investigation has been performed at the Flerov Laboratory of Nuclear Reactions, JINR.

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Introduction

The application of heavy ions of large mass is necessary for the decision of problems of the synthesis of new elements. Especially important in planning the experiments on the synthesis of new elements is to know the cross section of complete fusion. The cross sections of complete fusion in reactions with heavy ions up to values $Z_p \cdot Z_t = 1600$ are well described by the existing theoretical models. For $Z_p \cdot Z_t > 1600$ values the cross section of complete fusion dramatically fall.

There are different models for the description of complete fusion of massive nuclei. Most popular of them is the Macroscopic Dynamical Model of Swiatecki Ref.[1]. However, a lot of experimental data for reactions of cold synthesis cannot be explained even qualitatively within the framework of this model. For instance, a new elements with Z=107-112 were produced in GSI using targets close Pb (see, for example, Ref.[2]) . In these reactions the maxima of the excitation functions for the evaporation of one neutron lie below the Bass barrier. Complete fusion for these reactions in framework MDM required large excess (several tens MeV) of the collision kinetic energy above the entrance Coulomb barrier B_{Bass}. In Japan an approach is being developed on the basis of the Fluctuation-Dissipation Model (see, for example Ref.[3]), for the description of the fusion of heavy symmetric systems leading to the formation of transfermium nuclei. Estimation of the formation cross sections of SHE in standard statistical model taking into account the limitations on fusion from empirical systematics were made in Ref.[4].

In all listed models, as it seems, there is no systematic comparison with the existing experimental data. Such a comparison could give significant weight to the theoretical predictions. In FLNR (JINR) the new approach was elaborated to the description of complete fusion of massive nuclei based on dinuclear system concept Ref.[6]In the present work an attempt is undertaken to describe the existing data on cold synthesis of new elements on the basis of the *DNS* concept. We analysed various ("cold" and "hot") reactions leading to the synthesis of the new element with charge number 114.

2. Description of the theoretical approach

2.1. Basic assumptions of the DNS-concept

The motivation of the *DNS*-concept, the comparison of the *DNS*-concept and *MDM* have already been presented in Refs.[5] and [6]. Therefore, here we are going to point out only the basic assumptions of the *DNS*-concept, which are used in the analysis of the SHE-synthesis reactions. According to the *DNS*-concept the complete fusion process proceeds in the following way. On the capture stage, after full dissipation of the collision kinetic energy, a dinuclear system is being formed (well known from deep inelastic transfer reactions). Complete fusion is an evolution process in which the nucleons of one nucleus sequentially are transferred to the second nucleus. The main characteristic of the *DNS*, determining its evolution, is the potential energy of the system *V(Z,L)*, which calculated according to the next equation:

$$V(Z,L) = B_1 + B_2 + V(R^*,L) - [B_{CN} + V^{CN}_{rot}(L)], \qquad (1)$$

where B_1, B_2 and B_{CN} are the nuclear binding energies of the *DNS* nuclei and the compound nucleus, and Z is the atomic number of one of the nuclei in the *DNS*, L is the spin of the system. The value of *V(Z,L)* was normalised to the energy of rotating compound nucleus by $B_{CN}+V^{CN}_{rot}(L)$. The nucleus-nucleus potential *V(R,L)* incorporates the nuclear, Coulomb and centrifugal potentials:

$$V(R,L) = V_n(R) + V_c(R) + V_{rot}(R,L), \qquad (2)$$

where *R* is the distance between the centers of the nuclei in the *DNS*.

In calculating *V(R,L)*, the *DNS* was assumed to have the shape of two slightly overlapping nuclei. R^* is the value of *R*, at which the *DNS* is to be found at the bottom of the "pocket" in the potential *V(R,L)*. The nuclear potential $V_n(R)$ was calculated using the double folding method (see details in Ref.[7]). The centrifugal potential was calculated for the case of the rigid rotor moment of inertia.

2.2. Peculiarities in the complete fusion of two massive nuclei within the DNS concept.

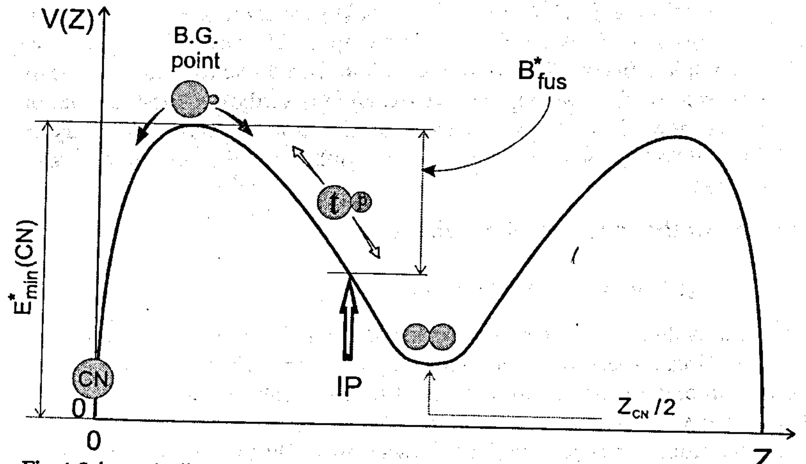

Fig. 1 Schematic illustrations of driving potential as a function atomic number the one of DNS nuclei. The possible moving of DNS and reaction input points are indicated with arrows.

Fig.1 presents the potential energy of the *DNS*, curve *V(Z,L=0)* exhibits two minima: the first one Z=0 - corresponding to complete fusion and the second one $Z=Z_{CN}/2=(Z_p + Z_t)/2$ - corresponding to the formation of a symmetric *DNS*. During the evolution *DNS* can decay into two nuclei. viz. quasi-fission takes place.

The synthesis of Superheavy Elements SHE is usually performed at projectile energies leading to excitation energies of the compound nucleus as low as possible. This ensures higher survival probability of the compound nucleus during its deexcitation. As can be seen from Fig.1, the main "heating" of the compound nucleus takes place during the descent of the *DNS* from the *B.G.* point. It is at this evolution stage that the greater part of the system's potential energy is transformed into thermal excitation. However, whether the *DNS* will reach the state of a compound nucleus or will undergo quasi-fission is determined already when approaching the *B.G.* point. At the same time, exactly at this evolution stage the *DNS* excitation energy is lowest. Thus, one can say that during the most important step to complete fusion, the *DNS* is in a cold state. This peculiarity in the evolution of the *DNS* in SHE-synthesis reactions required using real masses in calculating the potential energy *V(Z,L)* in equation 1. The deformation of the *DNS* nuclei formed during its evolution to the compound nucleus was taken into consideration. The deformation of the heavy nucleus was taken in the ground state, the deformation of the light nucleus -- in the 2^+ state.

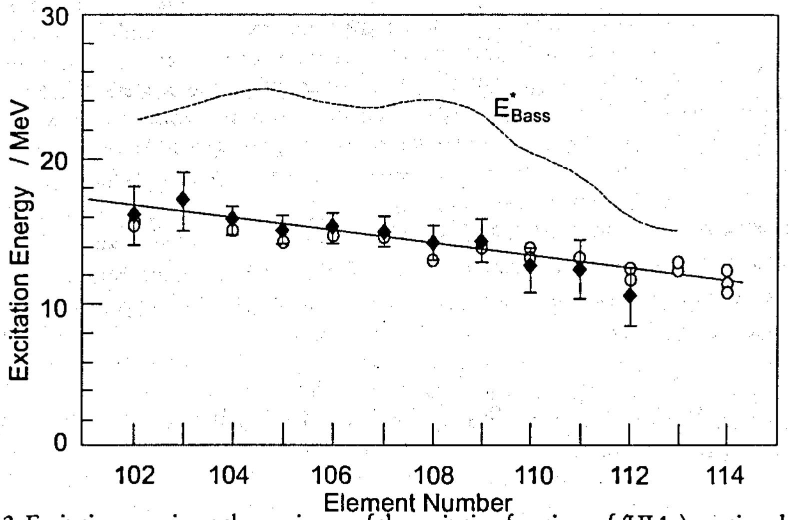

Fig. 2. Excitation energies at the maximum of the excitation functions of (HI,1n) reactions leads to nuclei with Z=102-114, o -- theoretical (see Table I) and balck signs - experimental data [8].

If the injection point of the reaction is situated to the right of the maximum in

V(Z,L=0) (the Businaro-Gallone (*BG*) point), the initial *DNS* may follow either of the two possible evolution paths: to a larger or smaller charge asymmetry. On the contrary, on the way to the compound nucleus the *DNS* has to overcome the potential barrier, B^*_{fus}, which is equal to the difference in *V(Z,L)* at the *B.G.* point and at the injection point of the reaction. The appearance of the inner fusion barrier B^*_{fus} [6] is due to the endothermic character of the process of nucleon rearrangement in the massive *DNS*, which leads the system in the direction of the compound nucleus. The energy necessary for this rearrangement is supplied from the *DNS* excitation energy *E*. The formation of the compound nucleus is not possible, if the *DNS* excitation energy is less than the value of B^*_{fus}.

2.3. Optimal energy for synthesis of SHE

Fig.2 demonstrates excitation energies in maximum of experimental and theoretical excitation functions of compound nuclei of elements with charge numbers *Z* from *102-114* produced in cold fusion *(HI,1n)* reactions. The curve indicates the value $E^*_{min}(CN)$ calculated on the Bass barrier [9]. From the Fig.2 one can see that our calculated values of E^*_{1n} are close to the experimental data.

2.4. The role of quasi-fission in the reactions of synthesis of SHE. Competition between complete fusion and quasi-fission

Another important characteristic of the fusion of massive nuclei, which manifests itself only in the *DNS*-concept, is the competition between complete fusion and quasi-fission. Due to the statistical character of the exchange of nucleons between the *DNS* nuclei, a certain probability exists that either the system reaches and overcomes the *B.G.* point, which leads to the formation of a compound nucleus, or the dinuclear system decay into two nuclei (undergoes quasi-fission). The more symmetric the reaction, the higher the inner fusion barrier B^*_{fus} which has to be overcome by the *DNS* on its way to the compound nucleus and, also, the stronger is the quasi-fission channel. In most known models of the complete fusion of nuclei, the formation cross section of compound nuclei σ_{fus} is not different from the capture cross section σ_C. In our approach the fusion cross section σ_{fus} is a part of the capture cross section σ_C

$$\sigma_{fus} = \sigma_c P_{CN} = \pi \bar{\lambda}_0{}^2 \sum_{l=0}^{l_{cr}} (2l+1) T(l, E_{cm}) \cdot P_{CN} \qquad (3)$$

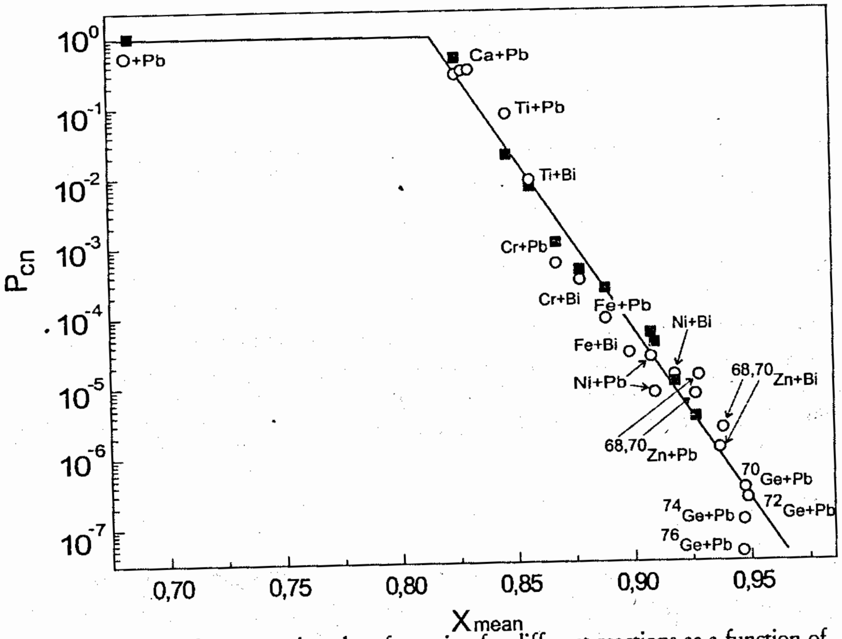

Fig. 3. Probability of compound nucleus formation for different reactions as a function of the fissility parameter xmean. Solid squares represent the PCN values extracted from the experimental data [12], open circles -- our calculations based on the model describing the competition between complete fusion [6] and quasi-fission

here $\bar{\lambda}_0^2$ is the de Broglie wave length of the relative motion of interacting nuclei, E_{cm} is the bombarding energy in the center-of-mass system, $T(l,E_{cm})$ is the penetration coefficient of the *l-th* partial wave through the potential barrier. $T(l,E_{cm})$ is approximated by the penetration factor of a parabolic barrier. P_{CN} is the probability of forming a compound nucleus in competition with quasi-fission [6]. In Fig.3 the values P_{CN}, calculated for different reactions with ^{208}Pb and ^{209}Bi targets.

The ratio of repulsive Coulomb forces and the attractive nuclear forces governs the moving of two nuclei into one. For a monosystem this ratio is given by the fissility parameter x. For two touching sphere configuration, taking into account that the proton and neutron ratio between the two partners is equilibrate very quickly ($\approx 10^{-22}$ sec). A modified parameter x_{mean} describing the ratio of Coulomb and nuclear forces has been defined according to [13] and [14]:

$$x_{mean} = (1/3) \cdot x_{eq} + (2/3) \cdot x_{fis}, \text{ where } x_{fis} = (Z^2/A)/(Z^2/A)_{cr},$$

$x_{eq} = 2x_{fis}(k^2 + k + k^{-1} + k^{-2})^{-0.5}$, where $k = (A_p / A_t)^{1/3}$ and

$$(Z^2 / A)_{cr} = 50.883[1 - 1.7826(\frac{A - 2Z}{A})^2].$$

5.2. Capture cross section

The capture cross section σ_c makes up a part of the total inelastic cross section

$$\sigma_c / \sigma_R = \frac{\sum_{l=0}^{l_{cr}} (2l+1) T(l, E_{cm})}{\sum_{l=0}^{\infty} (2l+1) T(l, E_{cm})}. \qquad (4)$$

The l_{cr} is the critical angular moment, at which the capture of a heavy ion occurs and an excited *DNS* is formed. The value of l_{cr} was taken from empirical systematics of the ratio σ_c/σ_R [10]. In the Fig.4 one can see the experimental data and our calculations σ_c for two type of reactions: with a ^{208}Pb target (left) and a ^{238}U target (right). The rather good agreement between the calculations and the experimental data is obvious.

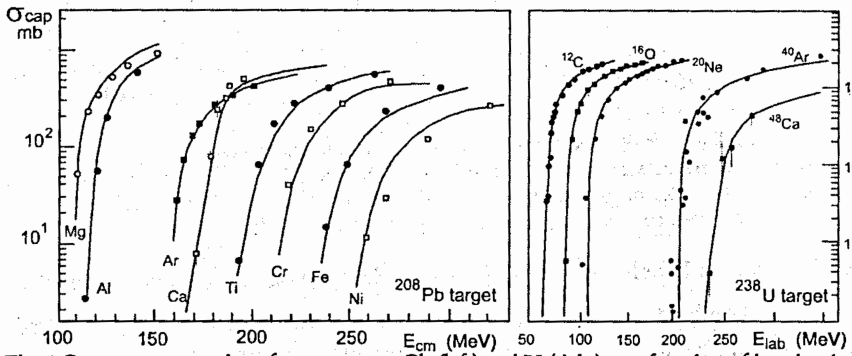

Fig. 4 Capture cross sections for two targets Pb (left) and U (right) as a function of bombardmer energy and different heavy ions. Points are experimental data, curves are result of calculation. Experimental data was taken from [20,30-33].

2.6. Survival probability

The production cross section for evaporation residues with emission of x neutrons from heavy compound nuclei can be written in a following form as:

$$\sigma_{xn}(E^*) \approx \sigma_{fus} \cdot P_{xn}(E^*) \cdot W_{sur}(E^*), \qquad (5)$$

where σ_{fus} is the compound nucleus formation cross section; E^* - excitation energy of compound nucleus; P_{xn} is the probability of evaporation of exactly x neutrons from the excited compound nuclei [11]; W_{sur} is the probability of survival of the heavy ($\Gamma_n/\Gamma_{tot} \approx \Gamma_n/\Gamma_f$) compound nucleus during its deexcitation

$$W_{sur}(E^*) \approx \prod_{k=1}^{x} (\frac{\Gamma_n(E_k^*)}{\Gamma_f(E_k^*)})_k, \qquad \underline{(6)}$$

where x is number of evaporated neutrons, k - the index of the evaporation step. For the partial widths of neutron emission and fission the following expressions have been used [9]:

$$\Gamma_n(E^*, L) \approx \frac{(2s+1)\mu}{(\pi\hbar)^2 \rho_m(U)} \int_0^{U-B_n} \sigma_{inv}(E_n) \rho_d(U - B_n - E_n) E_n dE_n, \qquad (7)$$

where U is the thermal energy of the mother nucleus, s - the spin of the emitted particle and μ - the reduced mass of the system (particle neutron plus daughter nucleus). The symbols m and d indicate the mother and the daughter nuclei, respectively. The inverse cross section σ_{inv} is calculated within the model described in [10].

$$\Gamma_f(E^*, L) \approx (2\pi\rho_\mu(U))^{-1} \int_0^{U_s - B_f} \rho_s(U_s - B_f - \varepsilon) d\varepsilon, \qquad (8)$$

In expression (8) the thermal energy U_s and the rotational energy E_s connected at the saddle point by the relation $U_s = E^* - E_r^s$. This form of the width Γ_f takes into account the change of the fission barrier of the rotating nucleus so far as $B_f(L) = B_f(0)-(E_r-E_r^s)$ (see details in [15]). To describe the level density as a function of the excitation energy, the well known Fermi-gas expression (see, for example, book [16])

$$\rho(E^*) = \left(\sqrt{\pi} \Big/ 12a^{1/4}(E^* - \delta)^{5/4} \right) \exp[S(E^*)], \qquad (9)$$

has been used. In (9) the dependence of the nucleus entropy S on the excitation energy E^* is determined by the relation: $S=2at$, using the connection of the temperature with the excitation energy of the nucleus $E^*=at^2$, here δ is correction accounting for even-odd effects [18]. The parameter of the level density $a=\pi^2 g_0/6$ is expressed through the density of single particle states near the Fermi energy $g_0 = f(E_f) = const$. The decrease of the influence of shell effects on the level density with increasing excitation energy is taken into account by the phenomenological expression [16]:

$$a(E^*) = \tilde{a}[1 + f(E^*) \Delta W / E^*], \qquad (10)$$

here $f(E^*)=1-exp(-\gamma \cdot E^*)$, ΔW is the shell correction in the nuclear mass formula,

$\tilde{a} = A(\alpha + \beta A)$ is the Fermi-gas value of the level density parameter, A is the mass number of nucleus. The empirical values of the parameters $\alpha=0.134\ MeV^{1}$, $\beta=-1.21\cdot10^{-4}\ MeV^{1}$, $\gamma=0.061\ MeV^{1}$ have been obtained in Ref.[18] from the analysis of the data on the level density with taking into account the contribution of the collective states to the total level density.

The fission barrier B_f is a sum of liquid drop B^{LD}_f and shell correction ΔW parts $B_f=B^{LD}_f+\Delta W$. To calculate W_{sur} need know the fission barrier of compound nuclei. For transfermium region of compound nuclei the B^{LD}_f is very small. To include effect of washing of shell corrections we used the next equation $B_f(E^*)=\Delta W\cdot exp(-\gamma\cdot E^*)$. For our calculation we used the value of $B_f(E^*=0)=B^{stat}_f$ from Ref.[17].

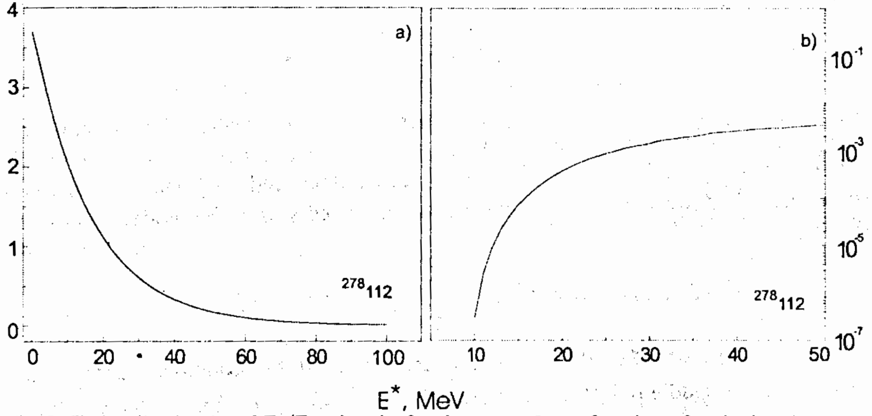

Fig. 5. Fission Barrier a) and Γ_n/Γ_f values b) for element 112 as a function of excitation energy.

In Fig.5 one can see that the dependence of the fission barrier and ratio Γ_n/Γ_f on E^* in region of maximums of excitation functions for (HI,1n) reactions (10-20 MeV) is very strong.

3. THE ANALYSIS OF REACTIONS USED FOR THE SYNTHESIS OF THE TRANSFERMIUM AND SUPERHEAVY ELEMENTS

3.1. Reactions of Cold Fusion

The "cold" method of synthesis of heavy elements where evaporation of one neutron has higher probability, named "cold fusion" (was proposed in Dubna by Yu.Ts. Oganessian Ref.[19]), was successfully used to produce new transfermium elements up to $Z=112$. One can see from Fig.6 that our approach allows rather good describe existent experimental data on cold fusion $(HI,1n)$ reactions.

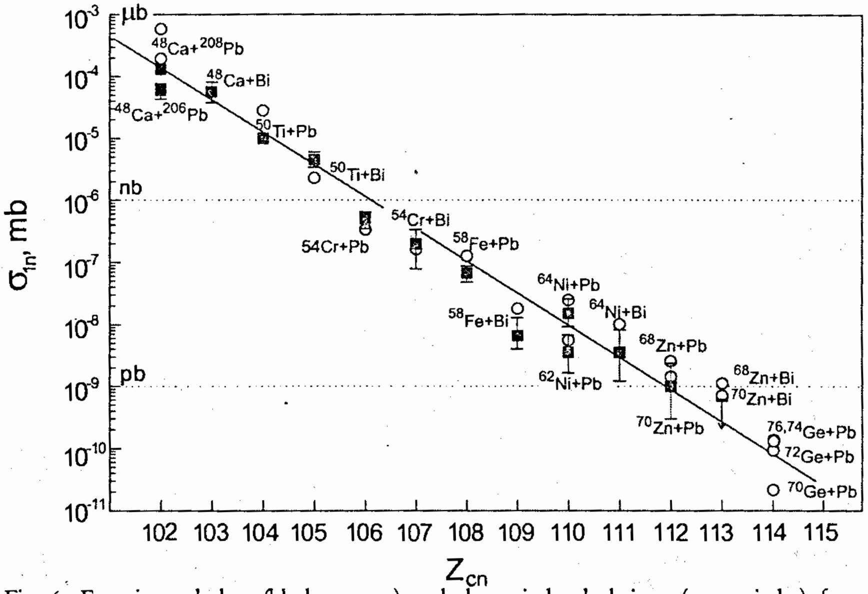

Fig. 6. Experimental data (black squares) and theoretical calculations (open circles) for synthesis of elements from 102 to 114 in cold fusion reactions (HI,1n), the combinations are noted in the figure. The line has been drawn to guide the eyes. The references on experimental data σ_{1n} see in Table I.

3.2. Hot fusion reactions

As one can see from Fig.6 σ_{1n} of reactions which leads to synthesis of the superheavy element with magic number $Z=114$ with use Pb target less than $1\ pb$.

Therefore we analysed another reaction ^{48}Ca+^{244}Pu=^{292}114, which was chosen for the synthesis of element 114 in FLNR (Dubna) (see, for example, Ref.[23]). There are experimental data in which a ^{48}Ca-beam was used to bombard targets of Pb, Th, U. For the reaction ^{48}Ca+^{208}Pb=^{256}102 measurements of the excitation functions for the evaporation of $1,2,3,4$ neutrons, as well as the fusion-fission cross section [20], which for heavy compound nuclei coincidences with the fusion cross section, have been measured. Therefore it seemed very interesting to analyse these reactions in the framework of the DNS concept.

In Fig.7 one can see calculations based on the DNS-concept for two reactions. For the $^{48}Ca+^{208}Pb=^{256}102$ reaction (left panel) our calculation rather well describes the experimental data for evaporation residue cross sections. For the $^{48}Ca+^{232}Th=^{280}110$ reaction (right panel), for which only σ_{3n} has been measured,

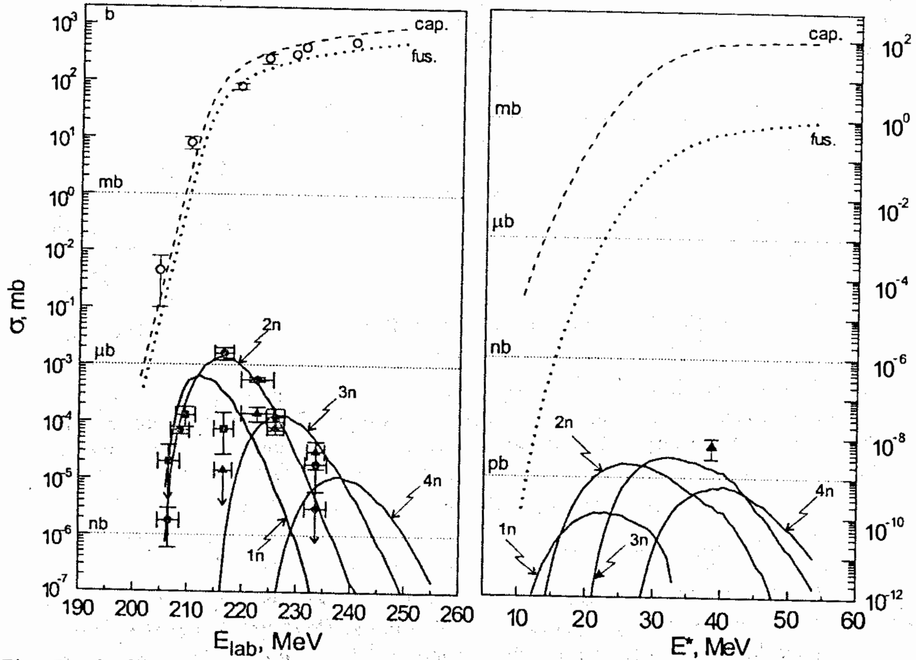

Fig.7 Results for the two reactions ^{48}Ca+^{208}Pb=^{256}102 (left) and ^{48}Ca+^{232}Th=^{280}110 (right). Signs o denote the experimental values of fusion-fission cross sections [20], solid points -- experimental values of σ_{xn} [20], the experimental value σ_{3n} for the right reaction was taken from Ref.[24], curves are the result of our estimations: dashed curves are calculations for σ_c, dotted curves - for σ_{fus}, solid curves - for σ_{xn}.

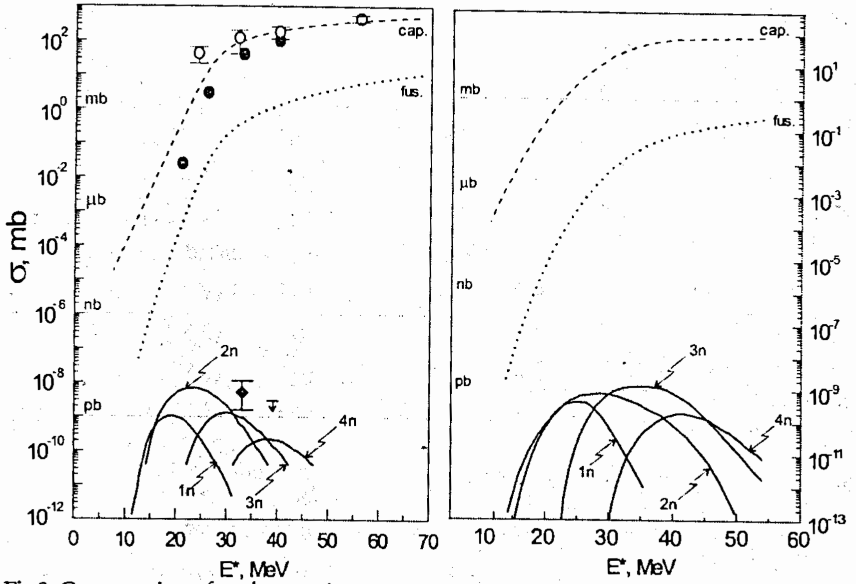

Fig.8 Cross sections for the reactions ^{48}Ca+^{238}U (left) and ^{48}Ca+^{244}Pu (right) leading to compound nuclei with Z=112 and Z=114, respectively. On the left, open and solid circles are capture cross sections from Ref.[25] and [26] correspondingly. Experimental data for σ_{xn} was taken from [27]. Different curves are theoretical calculations (explanation see in the caption of Fig.7).

our calculation is not in disagreement with the experimental point.

As one can see from Fig.8 our calculations for the ^{48}Ca+^{238}U=^{286}112 reaction agree with the experimental values. The right panel of Fig.8 shows our estimations for the cross sections for the ^{48}Ca+^{244}Pu=^{292}114 reaction. Comparing our estimations (see Fig.6) for the ^{76,74,72,70}Ge+^{208}Pb=^{284,282,270,278}114 reaction with these for the reaction ^{48}Ca+^{244}Pu=^{292}114 (see Fig.8), it follows that the latter one is more preferable.

Table 1 Results of our calculations for cold fusion reactions. The references on experimental values for reactions with Z_{CN}=104-112 see in Review [2] and references therein.

Reactions	E^*_{th} MeV	E^*_{exp} MeV	P_{CN}	σ^{th}_{1n} mb	σ^{exp}_{1n} mb	Ref.
^{48}Ca+^{208}Pb=^{256}102	15.6	16.0	$2.9\cdot10^{-1}$	$5.8\cdot10^{-4}$	$(1.3^{+0.4}_{-0.4})\cdot10^{-4}$	[20]
^{48}Ca+^{206}Pb=^{254}102	16.1	24.0	$3.3\cdot10^{-1}$	$1.9\cdot10^{-4}$	$(6.0^{+1.6}_{-1.6})\cdot10^{-5}$	[21]
^{50}Ti+^{208}Pb=^{258}104	15.2	15.0	$7.7\cdot10^{-2}$	$2.8\cdot10^{-5}$	$(1.0^{+0.13}_{-0.13})\cdot10^{-5}$	[2]
^{50}Ti+^{209}Bi=^{259}105	14.7	15.0	$7.9\cdot10^{-3}$	$2.1\cdot10^{-6}$	$(4.5^{+0.9}_{-0.9})\cdot10^{-6}$	[2]
^{54}Cr+^{208}Pb=^{262}106	14.5	15.0	$5.5\cdot10^{-4}$	$3.4\cdot10^{-7}$	$(5.0^{+1.4}_{-1.4})\cdot10^{-7}$	[2]
^{54}Cr+^{209}Bi=^{263}107	14.4		$3.2\cdot10^{-4}$	$1.6\cdot10^{-6}$	$(2.0^{+1.3}_{-1.2})\cdot10^{-7}$	[2]
^{58}Fe+^{208}Pb=^{266}108	12.9	14.0	$8.8\cdot10^{-5}$	$1.3\cdot10^{-7}$	$(6.7^{+0.75}_{-0.75})\cdot10^{-8}$	[2]
^{58}Fe+^{209}Bi=^{267}109	14.0	14.0	$2.9\cdot10^{-5}$	$1.8\cdot10^{-8}$	$(7.5^{+5.0}_{-3.5})\cdot10^{-9}$	[2]
^{62}Ni+^{208}Pb=^{270}110	13.9	13.8	$7.7\cdot10^{-6}$	$5.5\cdot10^{-9}$	$(3.5^{+2.7}_{-1.8})\cdot10^{-9}$	[2]
^{64}Ni+^{208}Pb=^{272}110	13.1	12.2	$2.5\cdot10^{-5}$	$2.4\cdot10^{-8}$	$(1.5^{+0.9}_{-0.6})\cdot10^{-8}$	[2]
^{64}Ni+^{209}Bi=^{273}111	13.2	13.5	$1.4\cdot10^{-5}$	$1.2\cdot10^{-8}$	$(3.5^{+4.6}_{-2.3})\cdot10^{-9}$	[2]
^{70}Zn+^{208}Pb=^{278}112	11.8	10.0	$7.3\cdot10^{-6}$	$1.4\cdot10^{-9}$	$(1.0^{+1.3}_{-0.7})\cdot10^{-9}$	[2]
^{68}Zn+^{208}Pb=^{278}112	12.3	10-12	$1.4\cdot10^{-5}$	$2.2\cdot10^{-9}$	$<1.3\cdot10^{-9}$	[2]
^{70}Zn+^{209}Bi=^{279}113	12.7	10-12	$1.3\cdot10^{-6}$	$6.4\cdot10^{-10}$	$<6.0\cdot10^{-10}$	[22]
^{68}Zn+^{209}Bi=^{279}113	12.8		$2.6\cdot10^{-6}$	$1.1\cdot10^{-9}$		
^{76}Ge+^{208}Pb=^{284}114	10.8		$3.3\cdot10^{-8}$	$1.2\cdot10^{-10}$		
^{74}Ge+^{208}Pb=^{284}114	10.8		$1.1\cdot10^{-7}$	$1.2\cdot10^{-10}$		
^{72}Ge+^{208}Pb=^{284}114	11.6		$3.5\cdot10^{-7}$	$9.5\cdot10^{-11}$		
^{70}Ge+^{208}Pb=^{284}114	12.4		$3.8\cdot10^{-7}$	$1.9\cdot10^{-11}$		

There exist also other estimations of cross section for the combination *^{48}Ca+^{244}Pu=^{292}114* (see Table II). One can see that our estimation is in rather good agreement with value of cross sections from Ref.[4]. Now in the FLNR an experiment is running to produce the isotope of element *114*, in the reaction *^{48}Ca+^{244}Pu=^{292}114*. This experiment is very important, since it would give a possibility to reach the island of stability, about which physicists of the whole world dream more than 30 years.

Table 2. Results of different estimations (maximal quantities) for cross sections values for ^{48}Ca+^{244}Pu=$^{292-xn}$114 reaction

Channel	E^*	Value	Ref.
σ_{3n}	35 MeV	3.5 pb	[4]
σ_{3n}	26 MeV	100 pb	[28]
σ_{ER}	37 MeV	10 pb	[29]
σ_{3n}	32 MeV	20 pb	[23]
σ_{3n}		$<5\cdot10^{-4}$ pb	[12]
σ_{3n}	35 MeV	1.5 pb	[present work]

Conclusions

The *DNS* concept was used in the analysis of existent experimental data on reactions leading to the synthesis of elements *102* and *112*. The attempt to synthesise element *114* was also analysed. The method applied in this article well describes a wide set of experimental data on reactions of cold synthesis (reactions with evaporation of one neutron *(HI,1n)*) what concerns the maxima of the excitation functions (see Fig.2), and their absolute values (see Fig.6). The *DNS* concept allows to carry out calculations of the inner fusion barrier B^*_{fus} for synthesis reactions, which in turn gives an estimation of the threshold *ΔE* for complete fusion. The *DNS* concept allows to estimate powerful influence the competition between complete fusion and quasi-fission in *SHE* synthesis reactions, which gives the probability P_{cn} of forming a compound nucleus after capture. In "cold" fusion reactions, the quasi-fission is the main factor determining the decrease of *SHE*- production cross sections when increasing the atomic number of the synthesised *SHE*. It was shown that the reaction *^{48}Ca+^{244}Pu=^{292}114* for the synthesis of element *114*, suggested in *FLNR* [23], is more preferable compared with the reaction of a *Ge*-beam on a *Pb*-target.

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