объединенный
институт
ядерных
исследований
дубна

E2-84-651

EXPERIMENTAL STUDIES OF THE FORMATION AND RADIOACTIVE DECAY OF ISOTOPES WITH Z = 104-109

Submitted to International Conference
on Nuclear and Radiochemistry
(Lindau, 8-12 October 1984)

1984

**Yu.Ts.Oganessian, M.Hussonnois[1], A.G.Demin,
Yu.P.Kharitonov, H.Bruchertseifer[2], O.Constantinescu[3],
Yu.S.Korotkin, S.P.Tretyakova, V.K.Utyonkov,
I.V.Shirokovsky, J.Estevez**

[1] Institut de Physique Nucléaire, Orsay, France
[2] Zentralinstitut für Isotopen- and Strahlenforschung, Leipzig, DDR
[3] Institute of Nuclear Physics and Engineering, Bucharest, Romania

INTRODUCTION

The transfermium nuclides which can be synthesized effectively by heavy-ion reactions can undergo electron capture, alpha-decay and spontaneous fission. The stability of isotopes of the heaviest elements is determined, as a rule, by the latter two decay modes, the probability of which is associated with the energy of the nucleus in the ground and in deformed states.

While in the case of alpha-decay the nuclear lifetime depends mainly on the value of $Q_a = M(Z, N) - M(Z-2, N-2) - M_a$, which can be obtained from the nuclear mass systematics, for spontaneous fission the situation turns out to be more complicated.

The spontaneous fission half-life of the nucleus is a complex dynamical quantity determined by the probability of penetration through the potential barrier, which in turn has a complex structure due to the considerable influence of nuclear shells on deformation energy. In the region of the transuranium elements, the role of shell effects grows significantly, as the atomic number of the nucleus (and the fissility parameter x) increases. For $x > 0.8$-0.9, the height and shape and even existence itself of the potential barrier are entirely due to nuclear structure. It is possible to assume that this will lead to strong changes in the character of the dependence $T_{SF}(Z, N)$, especially for the transactinide elements, of which kurchatovium ($Z = 104$) /1/ is the first one. As for all the known doubly-even isotopes with $Z = 104$ $T_{SF} \ll T_a$, for the heavier elements with $Z > 104$ the problem of stability against spontaneous fission is rather important. In the absence of results (or with negative results) on the synthesis of superheavy nuclei with $Z = 114$-116 /2,3/, an answer to this question would be a straight-forward test of the hypothesis about the theoretically predicted /4/ "island of stability" of superheavy elements.

The shell structure effect on the collective nuclear motion can manifest itself not only in nuclear fission, but also in the "reverse process", the fusion of two complex nuclei followed by the formation of a compound nucleus.

The probability of the formation of complete fusion reaction products is determined by the following two factors: the compound nucleus formation cross section $\sigma_{CN}(E^*)$ and the survival probability for the final product with $Z = Z_{CN}$, each of which depends in some ways on the excitation energy E^*.

At the same time the role of shell effects decreases rapidly with the increasing excitation energy of the nucleus.

Under these conditions the "cold fusion" reactions leading to the formation of a compound nucleus with the minimum possible excitation energy ($E^* \sim 15$-25 MeV) are advantageous. These reactions were used in our experiments to synthesize and investigate the radioactive properties of the heaviest elements of the Periodic Table. Some results of those studies are given below.

EXPERIMENTAL PROCEDURE

To synthesize isotopes of the transactinide elements with Z = 104-111 use was made of reactions between the target nuclei with atomic and mass numbers lying close to the magic numbers Z = 82 and N = 126 (mainly ^{208}Pb and ^{209}Bi) and projectiles with masses A_1 = 48-64 a.m.u. The maximum ion energy was chosen to be equal to 5.5 MeV/nucl. The intensity of the $^{48-50}$Ti, ^{54}Cr, ^{55}Mn, ^{58}Fe, and ^{64}Ni heavy ion beams produced at the U400 cyclotron ranged from 5×10^{12} to 5×10^{13} ions/s.

The experimental scheme is shown in fig.1.

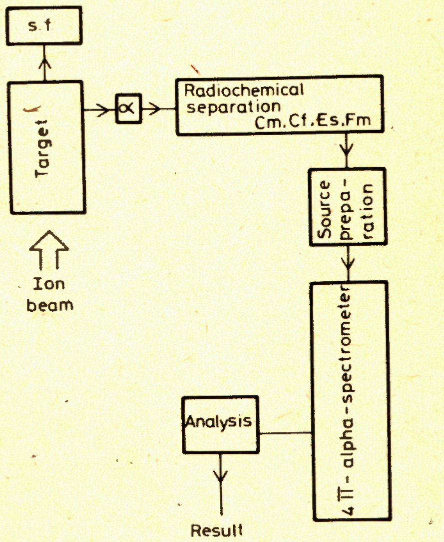

Fig.1. Experimental scheme.

If the nuclei formed in the reaction undergo spontaneous fission, it will be detected by fission fragment track detectors (on-line) and their half-life can be determined from the track distribution. In the case of alpha-decay the sought nuclei can be identified (off-line) by detecting the daughter (long-lived) products using the radiochemical separation of isotopes of Cm, Cf, Es, and Fm with the subsequent measurement of the energy and time spectra of their alpha-decay/5/. In both cases even during a long exposure (about 20 days), the conditions of practically zero background are provided, and the experimental sensitivity is such that the observation of one spontaneous fission or alpha-decay event corresponds to an activity production cross section equal to about 3×10^{-37} cm^2.

The experiments were carried out along the following two lines: (i) study of some characteristics of "cold fusion" re-

Table 1

Reaction	E_{lab}^{max} ($\frac{MeV}{nucl}$)	Beam dose ($\times 10^{18}$)	Observed nucleus	Number of fragment tracks	Number α-particles	b	Cross section[a] ($\times 10^{-33}$ cm^2)
$^{208}Pb(^{50}Ti,\gamma)^{258}104$	5.45	0.8	^{246}Cf		65	α(0.13)	0.6
$n)^{257}104$			^{253}Fm		72	α(0.12)	5
$2n)^{256}104$			$^{256}104$	7440		s.f(0.99)	6
			^{240}Cm		14	α(0.01)	6
$3n)^{255}104$			$^{255}104$	380		s.f(0.5)	0.6
$p,n)^{256}103$			^{252}Fm		<6	α(1.0)	≤0.02
$\alpha,2n)^{252}102$			^{240}Cm		14	α(0.73)	<0.06
$^{208}Pb(^{49}Ti,n)^{256}104$	5.53	0.8	$^{256}104$	120		s.f(0.99)	~0.2
$2n)^{255}104$			$^{255}104$	840		s.f(0.5)	~2
$\alpha,n)^{252}102$			^{240}Cm		1	α(0.73)	≤0.004
$p,2n)^{254}103$			^{244}Cm		0	α(1.0)	≤0.005
$^{208}Pb(^{48}Ti,n)^{255}104$	5.40	0.6	$^{255}104$	95		s.f(0.5)	0.2
$p,n)^{254}103$			^{246}Cf		10	α(0.54)	0.008
$\alpha\ )^{252}102$			^{240}Cm		0	α(1.0)	≤0.003

a) For (^{50}Ti, xn) excitation function width ΔE = 10 MeV.

actions and (ii) the synthesis and determination of the stability of new nuclides against various modes of radioactive decay.

The possibility of detecting the primary alpha-decaying products of the (HI, xn) reactions by registering their daughter, granddaughter, etc., products is determined by the absence of other channels in which the latter can be produced independently. To establish the extent to which this condition is satisfied, the reactions ^{208}Pb + $^{48-50}$Ti were studied. In these reactions primary complete-fusion products, the known isotopes of elements 104 with A = 255-258 and their radioactive decay products, isotopes of elements ranging from Cm to Fm, can be detected in the same experiment.

The results of these experiments (see table 1) show that in the given ion energy range (from the reaction thresholds to the maximum value of 5.5 MeV/nucl.) the observed alpha-decay and spontaneous fission events all are related to the 104 element isotopes produced in the reactions $^{208}Pb(^{48-50}Ti,xn)$ for

$x \leq 3$. The emission probability for charged particles (protons, alpha-particles or the heavier clusters) is strongly suppressed relative to the probability of complete fusion followed by neutron evaporation, irrespective of the assumptions made concerning the possible mechanism of this process. The upper limits of the (Ti,pxn) or (Ti,αxn) reactions cross sections have been determined to be at a level of about one hundredth fraction of the (Ti,xn) reaction cross section.

This feature of the "cold fusion" reactions provides the possibility of detecting and identifying alpha-emitters by detecting their decay products whose properties are well known. Although in the given case only the fact of alpha-decay is established, without measuring the alpha-decay radiation characteristics of the primary nuclide, this method has some advantages in terms of the detection sensitivity for the rare events of new element nuclei decay.

EXPERIMENTS TO SYNTHESIZE DOUBLY-ODD ISOTOPES WITH Z = 105, 107, 109, AND 111

In the experiments to synthesize isotopes with Z = 105, 107, 109, and 111 a ^{209}Bi target was bombarded with ^{50}Ti, ^{54}Cr, ^{58}Fe, and ^{64}Ni ions. The reactions involved in such systems seem to be optimal ones in terms of "cold fusion", i.e., for the production of slightly excited compound nuclei. In the case of the evaporation of one neutron they should lead to the formation of the doubly-odd isotopes ^{258}105, ^{262}107, ^{266}109, and ^{272}111, which are expected to be most stable against spontaneous fission and be genetically linked in alpha-decay (except for ^{272}111).

The alpha-decay of the isotopes ^{258}105, ^{262}107, and ^{266}109 leads to the production of the long-lived alpha-emitter ^{246}Cf and its daughter product ^{242}Cm, the yields of which (and, consequently, the yield of primary reaction products as well) can be determined with the high accuracy in off-line radiochemical experiments (see fig.2). In the case of the reaction ^{209}Bi + ^{64}Ni → 111 the isotope ^{252}Fm plays a similar role.

In the same experiments spontaneous fission events due to electron capture in the isotope ^{258}105 ($T_{1/2}$ = 4 s) were registered, permitting the independent determination of the isotopes ^{258}105, ^{262}107, and ^{266}109 yields in the corresponding reactions.

The absence of the characteristic alpha-activity due to ^{246}Cf (or ^{252}Fm), equally as spontaneous fission with $T_{1/2}$ = = 4 s, can indicate that the primary isotope undergoes spontaneous fission. In this case it is possible to detect by fission fragment track detectors a new spontaneously fissioning acti-

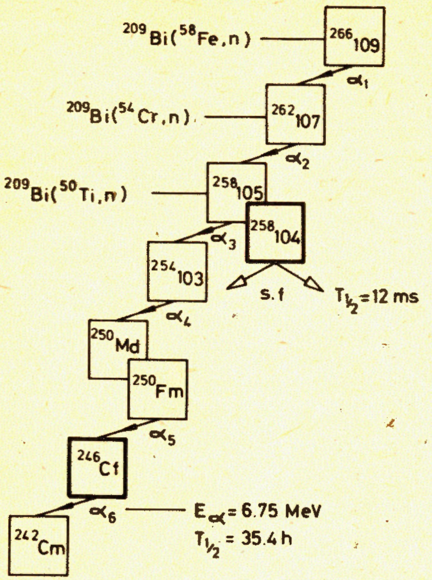

Fig.2. Sequential α-decay chain for doubly-odd nuclei ^{258}105, ^{262}107, and ^{266}109, leading to ^{246}Cf production. The reactions leading to the synthesis of these nuclides are given on the left.

vity with $T_{1/2} \approx T_{SF} < T_\alpha$, where T_α is its partial alpha-decay half-life.

The alpha-spectra of the Cf fraction and the 6.75 MeV alpha-time distribution obtained in those experiments are presented in figs.3 and 4. In more detail the experimental data are given in Table 2.

The ^{246}Cf yield (as well as the spontaneous fission activity with $T_{1/2}$ = 4 s) decreases by approximately one order of magnitude in going from ^{258}105 to ^{262}107, which is in good agreement with known data on the production cross sections for these isotopes /6,7/ and then decreases by almost two orders of magnitude for the nucleus ^{266}109. In the reaction ^{209}Bi + ^{58}Fe a total of only 7 events of ^{246}Cf alpha-decay and one track of a spontaneous fission fragment with time coordinate t = 1.8 s have been detected*.

It cannot be excluded a priori that the sharp decrease in the yield from the ^{209}Bi(^{58}Fe,n) reaction is due to ^{266}109 spontaneous fission. However in a separate experiment it was shown that in this reaction the cross section for producing the spontaneously fissioning nuclide with $T_{1/2}$ = 2-8 ms does not exceed 2×10^{-36} cm^2. Hence it is possible to conclude that both the isotope ^{266}109 and the doubly-odd isotopes with Z = = 105 and 107 undergo mainly alpha-decay. On the basis of the experimental values of half-lives for the isotopes ^{258}105 and ^{262}107 (ref. /7/), and from the alpha-decay half-lives systematics for ^{266}109, one can estimate the lower limits of spontaneous fission half-lives for these nuclei, which are shown in fig.7b.

*In the case of the reaction ^{209}Bi + ^{58}Fe → 109 comparison with the data obtained by G.Münzenberg et al. /8/ is not informative because of the statistical uncertainty of the results based on the detection of only one event.

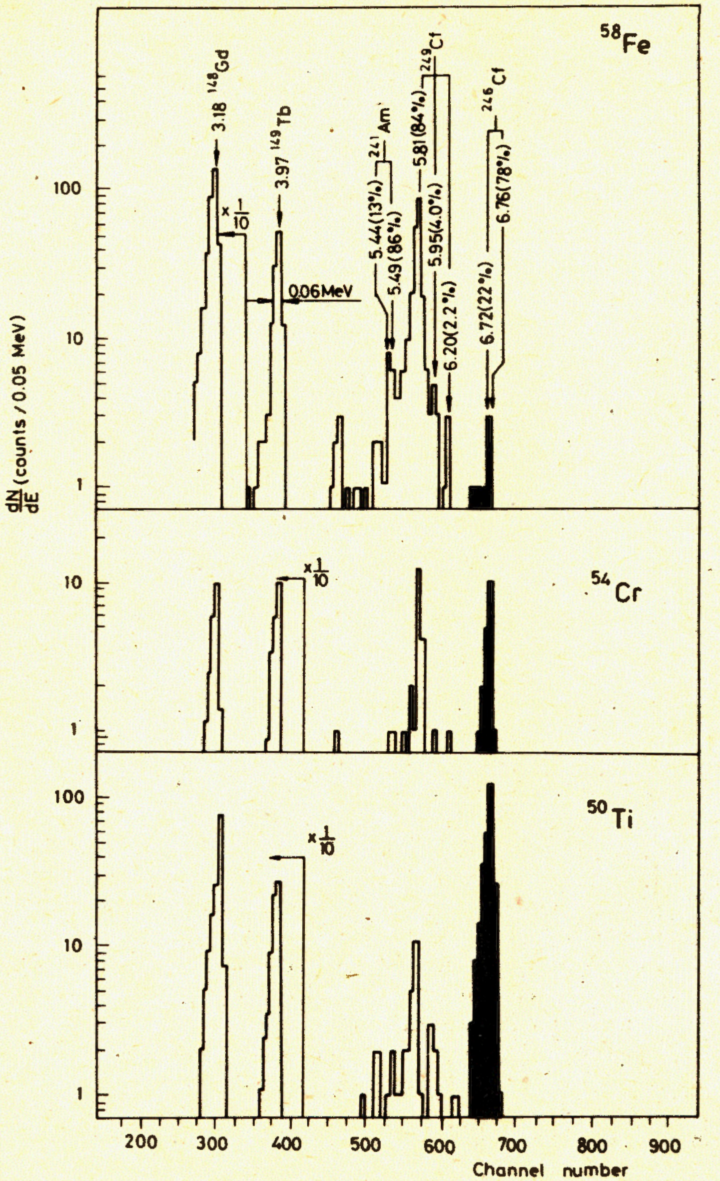

Fig.3. The α-particle spectra for the Cf-fractions obtained by bombarding a ^{209}Bi target with ^{58}Fe, ^{54}Cr, and ^{50}Ti ions. The arrows indicate the tabular energy (MeV) values and the probabilities of the α-radiation transitions in the nuclei present in the sample. The 3.18 MeV and 3.97 MeV peaks, as well as the complex spectrum having a maximum at 5.81 MeV, apply to the reference activities ^{148}Gd, ^{149}Tb, and ^{249}Cf, respectively. The 6.75 MeV α-particles are due to ^{246}Cf.

Table 2

Reaction	E_{lab}^{max} (MeV/nucl)	Beam dose ($\times 10^{18}$)	^{258}105 Number of tracks	^{258}105 $T_{1/2}$ (s)	^{246}Cf Number of α-particles	^{246}Cf $T_{1/2}$ (h)	$b_{E.C}$	Yield ($\times 10^{-16}$/ion)	Reaction cross section[a)] ($\times 10^{-33}$ cm^2)
^{209}Bi(^{50}Ti, n) ^{258}105	5.3	0.26	282	$4.2^{+1.6}_{-0.5}$	500	$34.5^{+2.2}_{-2.2}$	0.25	90	2.7
^{209}Bi(^{54}Cr, n)^{262}107	5.4	0.5.	28	$2.8^{+1.4}_{-0.7}$	58	35^{+23}_{-10}	0.21	6.5	0.2
^{208}Pb(^{55}Mn, n)^{262}107	5.5	6	165	$4.2^{+1.4}_{-1.0}$	113	40^{+6}_{-5}	0.2	2.5	0.1
^{209}Bi(^{55}Mn; p, n)^{262}107	5.55	6			0			<0.07	<0,002
^{209}Bi(^{58}Fe, n)^{266}109	5.5	3.6	1		7	35^{+39}_{-14}		0.1	0.003
^{208}Pb(^{59}Co, n)^{266}109	5.5	1.4	1		0			≤0.02	≤0.002
^{209}Bi(^{64}Ni, n)^{272}111	5.65	0.4	0		0[b)]			<0.1[c)] <0.3[b)]	<0.004 <0.01

a) For (HI, n) excitation function width ΔE = 10 MeV.

b) For ^{252}Fm in the assumption of α-decay $^{272}111 \to \ldots \to {}^{252}$Fm.

c) In the assumption of spontaneous fission of ^{272}111.

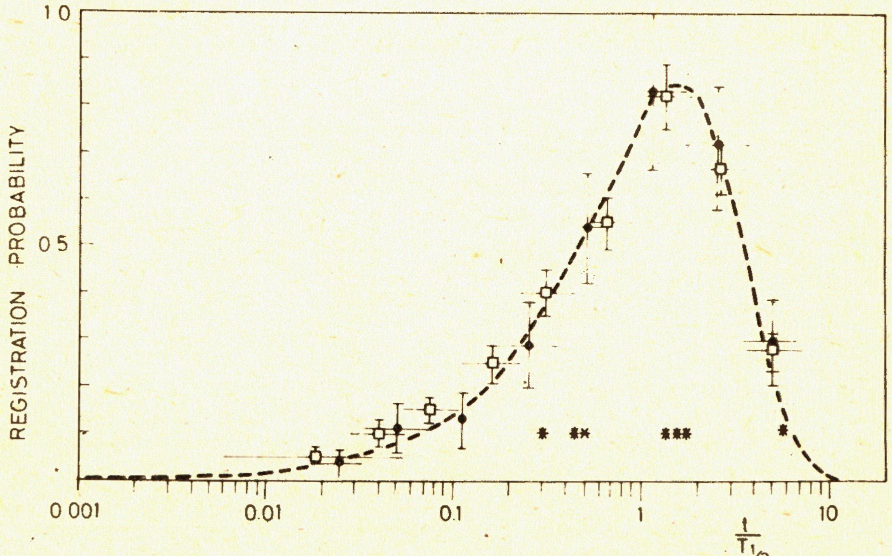

Fig.4. The time distributions of 6.75 MeV α-particles from the Cf fraction, measured in the following reactions: ^{209}Bi(^{50}Ti, n) ^{258}105 (□), ^{208}Pb(^{55}Mn, n)^{262}107 (●), ^{209}Bi(^{58}Fe, n)^{266}109 (*). The dashed line is a calculation for the isotope ^{246}Cf ($T_{1/2}$ = 37.5 h).

EXPERIMENTS TO SYNTHESIZE DOUBLY-EVEN AND EVEN-ODD ISOTOPES WITH Z = 104, 106, AND 108

The comparatively high stability of doubly-odd nuclei against spontaneous fission can be to a considerable extent due to the double hindrance factor because of the odd values of Z and N. Therefore, of special interest are studies of even isotopes with $Z > 104$.

Experiments were carried out by bombarding targets made of enriched $^{206-208}$Pb by $^{48-50}$Ti, ^{54}Cr, ^{58}Fe as well as ^{209}Bi with ^{55}Mn ions. The results of these experiments are presented in Table 3.

In the reactions ^{208}Pb($^{48-50}$Ti, xn) $\rightarrow$ 104, used to evaluate the role of processes involving charged particle emission, the known isotopes ^{255}104, ^{254}104, and ^{257}104 were produced the spontaneous fission probabilities of which are equal to about 50%, 99%, and <3%[9], respectively. The isotope ^{257}107 does not undergo spontaneous fission with noticeable probability and its α-decay leads to the production of short-lived isotopes up to ^{241}Cm ($T_{1/2}$ = 33 days, b_{EC} = 99%) the detection of which by our technique is impossible. However, as a result of electron capture which occurs in ^{257}104 and ^{253}102 with ~17% probability the isotope ^{253}Fm (b_{EC} = 88%) is produced. The latter then passes to ^{253}Es ($T_{1/2}$ = 20 days, E_α = 6.63 MeV), which is sufficiently convenient for radiochemical experiments (see fig.5).

Thus the observation of spontaneously fissioning activities with half-lives of 1.7 s and 6.7 ms, as well as of ^{253}Es α-radiation, allows one to determine the yields of the isotopes ^{255,256,257}104, respectively (see fig.6).

The same activities were detected in the reactions $^{206-208}$Pb + ^{54}Cr leading to the formation of isotopes of element 106 with A = 259, 260, and 261. Analysis of data obtained in these experiments shows that the isotopes $^{259-261}$106 undergo mainly α-decay.

This conclusion is especially important for the doubly-even ^{260}106 ($T_{1/2} \approx$ 3 ms) the α-decay of which leads to the isotope ^{256}104 ($T_{1/2}$ = 6.7 ms) that undergoes spontaneous fission with a probability of about 100%. A similar ratio of the probabilities of the main decay modes for the transfermium parent and daughter isotopes has been observed for the first time, indicating that the partial spontaneous fission half-life does not decrease as one moves from Z = 104 to Z = 106[10].

The studies of the reactions ^{209}Bi + ^{55}Mn and ^{207,208}Pb + ^{58}Fe lead to some conclusions concerning the properties of isotopes of element 108. The ^{255}104 and ^{253}Es yields allow one to determine the production cross sections for the even-odd isotopes ^{263}108 and ^{256}108 that decay by α-emission. The α-decay characteristics of the isotope ^{265}108 (E_α = 10.36 MeV, $T_{1/2}$ =

Table 3

Reaction	E_{lab}^{max} $(\frac{MeV}{nucl})$	Beam dose ($\times 10^{18}$)	Number of tracks	$T_{1/2}$	Number of α-particles	$b_{s.f}$	Yield ($\times 10^{-15}$/ion)	Reaction cross section a) ($\times 10^{-33} cm^2$)
^{208}Pb(^{50}Ti, n)^{257}104	5.45	0.8			72(^{253}Fm)		15	5
2n)^{256}104			7440	6.7±0.2 ms		0.99	17	6
3n)^{255}104			380	1.7±0.2 s		0.5	2	0.6
^{208}Pb(^{54}Cr, n)^{261}106	5.5	0.5			34(^{253}Es)	<0.5	1	0.3
2n)^{260}106		1.6	472	6^{+2}_{-1} ms		≲0.2	1	0.4
3n)^{259}106		0.5	16			<0.5	0.6	0.02
^{208}Pb(^{58}Fe, n)^{265}108	5.5	3.0			3(^{253}Es)		0.1	0.004
2n)^{264}108		3.2	7	8^{+20}_{-4} ms			0.05	0.002
^{207}Pb(^{58}Fe, n)^{264}108	5.5	2.2	13	6^{+5}_{-2} ms			0.2	0.005
^{209}Bi(^{55}Mn, n)^{263}108	5.5	13.0	21	$1.1^{+0.6}_{-0.4}$ s			0.05	0.002

a) For (HI, xn) excitation function with ΔE = 10 MeV.

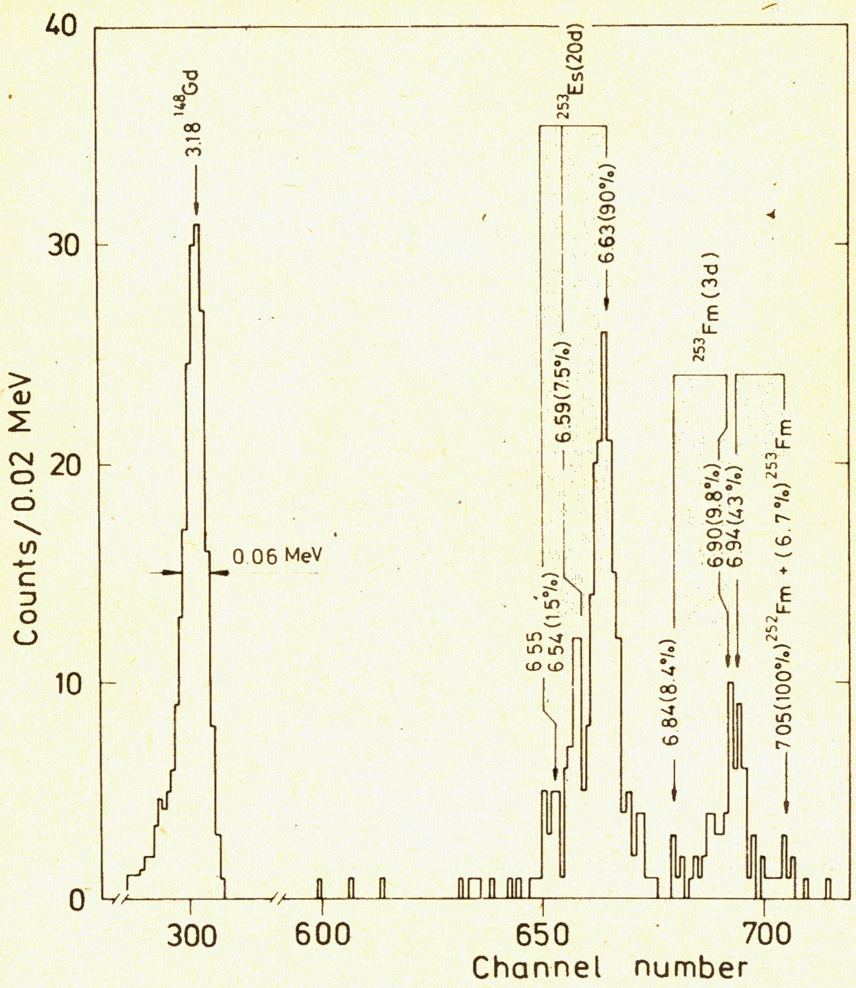

Fig.5. The α-particle spectrum for the Fm *fraction obtained by bombarding* ^{208}Pb *with* ^{50}Ti *ions, measured during 7 days. The arrows indicate the tabular energy values (MeV) and the probabilities of α-radiation transitions in nuclei present in the sample.*

2 ms) were established by G.Münzenberg et al., who synthesized this isotope in the reaction ^{208}Pb(^{58}Fe, n) /11/.

The time distribution of the 20 spontaneous fission fragment tracks observed in the reactions ^{207,208}Pb + ^{58}Fe does not differ within the experimental inaccuracy from that observed earlier for the isotope ^{260}106. As the ^{264}108 α-decay half-life (we estimate it to be T_α (^{264}108)~0.1 ms) is almost two

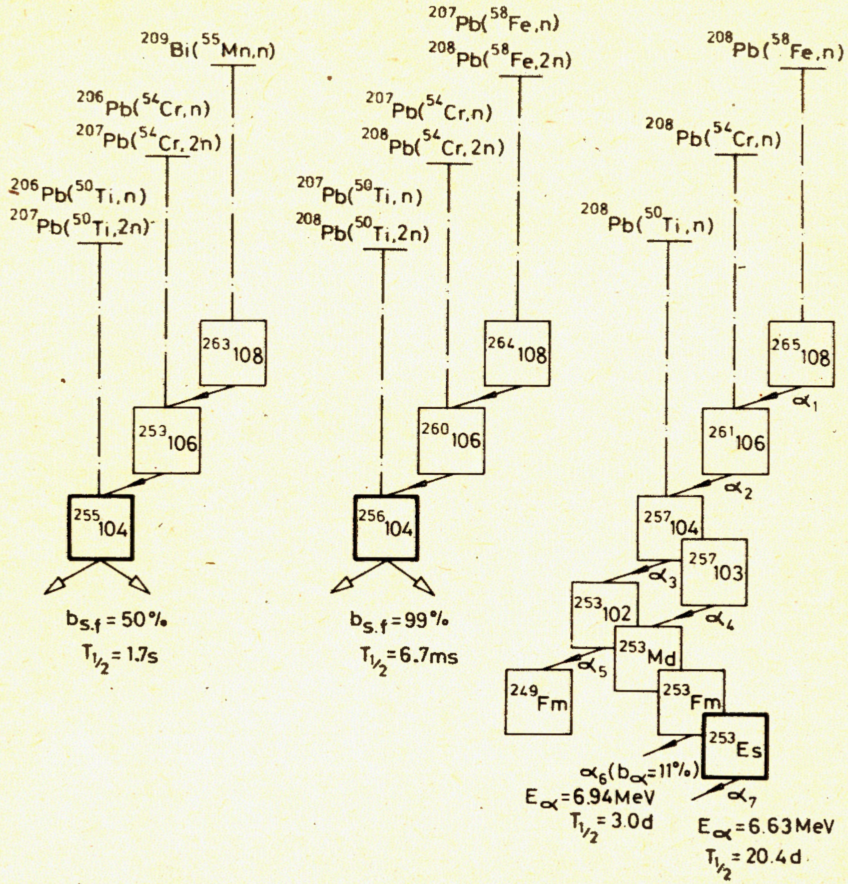

Fig.6. The decay chains of 108 element isotopes which lead to the formation of ^{255}**104**, ^{256}**104** *and* ^{253}**Es**. *The reactions used for synthesis in the present paper are indicated in the upper part of the figure.*

orders of magnitude smaller than that observed, it is natural to conclude that the predominant decay mode of the doubly-even isotope ^{264}108 is also α-decay followed by the formation of the daughter α-emitter ^{260}106, so that in the experiment the spontaneous fission of the granddaughter product ^{256}104 is observed /12/.

Thus nuclear stability is determined by α-decay ($T_\alpha < T_{SF}$) already for the two doubly-even isotopes ^{260}106 and ^{264}108.

Based on the experimental or calculated values of T_α for all the nuclei studied it is possible to estimate their partial half-lives for spontaneous fission. These data, together with the earlier ones, are presented in fig.7a.

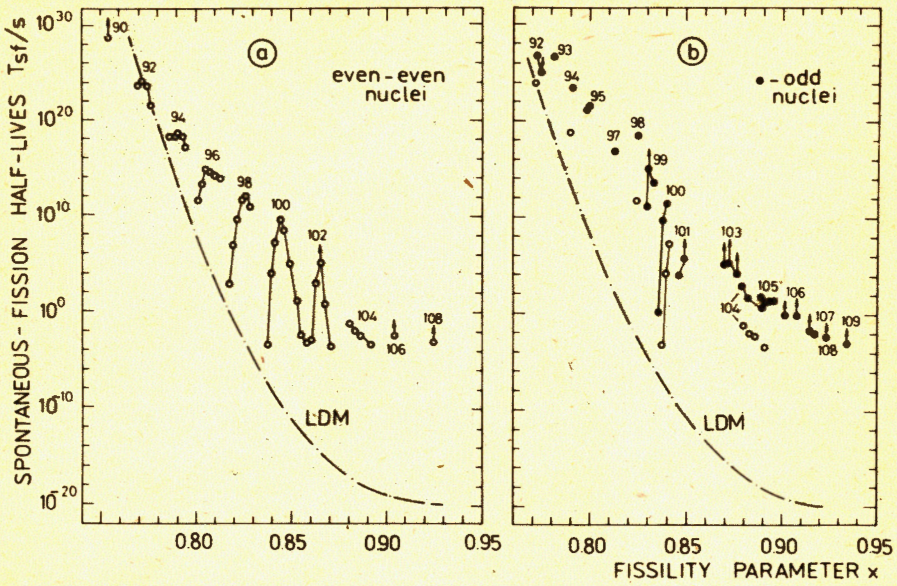

Fig.7. Experimental values of spontaneous fission half-lives of the Z ≥ 90 nuclei, as a function of the fissility parameter

$$x = \frac{Z^2/A}{50.883\{1 - 1.7826\,[(N-Z)/A]^2\}}$$

a) nuclei with even numbers of protons and neutrons; b) odd-mass nuclei. The dash-dotted line corresponds to the liquid-drop fission barriers and is normalized to the ^{236}U *spontaneous-fission half-life (see a review*[13]*).*

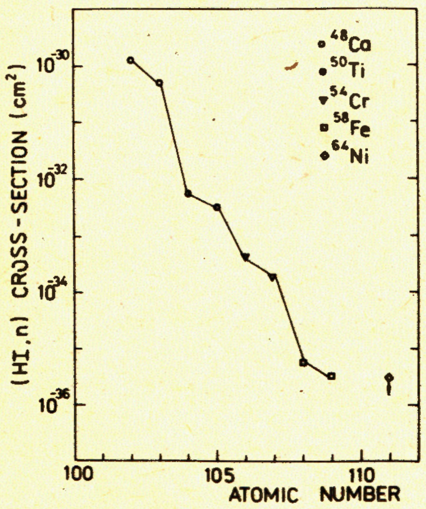

Fig.8. Dependence of the (HI, n) reaction cross section on the compound nucleus atomic number.

CONCLUSION

As one can see from Fig.7, the spontaneous fission half-lives of nuclei with Z = 104-109 exceed by a factor of $10^{15} - 10^{18}$ the T_{SF} values predicted by the liquid drop nuclear model. This shows that nuclear stability against spontaneous fission is determined in this region by the presence of the "shell" fission barrier. Theoretical calculations [14] suggest that its height and shape vary slightly for the given values of Z and N. Thus one should not expect strong systematic variations in the partial half-lives T_{SF} in this (and even wider range of Z and N values). Hence it follows that the role of α-decay as the main process competing with spontaneous fission for the heavier nuclei will be more essential than expected, as it has already been observed for the doubly-even isotopes of elements 106 and 108.

The problem of synthesizing still heavier elements ($Z > 109$) is illustrated in fig.8, which shows the cross section $\sigma(Z_{CN})$ for producing heavy nuclei in "cold fusion" reactions as a function of Z_{CN} = 102-109. The (HI, n) reaction cross section decreases considerably with growing Z_{CN}, and the dependence $\sigma(Z_{CN})$ has irregular character. One can observe considerable changes in moving from Z = 102 to Z = 104, as well as for Z > 107, which are difficult to interpret quantitatively.

The mechanism of compound nucleus formation in the heaviest nuclear systems is likely to be determined not only by the macroscopic characteristics of nuclear matter but also by the structure factors. In addition, the complex dynamical picture of fusion can change significantly with increasing energy and angular momentum in the entrance channel of the reaction.

In this situation it is necessary to accumulate additional experimental data in the region of the known nuclei with Z>104 and to carry out direct experiments to synthesize the heavier elements with Z ≥ 109. Unfortunately the sensitivity of our experiments with ^{64}Ni ions was insufficient for detecting the decay of the Z = 111 nuclei and we intend to continue these experiments.

If strong restrictions on compound nucleus formation arise in the Pb + HI reactions with increasing projectile mass [15], an alternative reaction can be fusion involved in considerably more asymmetric systems [16]. In this case the role of Coulomb interaction decreases compared with the more symmetric reactions Pb + HI, while the compound nucleus excitation energy increases. It should be noted that the latest experiment along this line refers to the reaction $^{249}Cf(^{18}O,4n)^{263}106$ in which the compound nucleus has an excitation energy of about 50 MeV [17].

Thus in order to advance in the direction of the heavier elements with Z > 109 and to synthesize the superheavy nuclei more thorough studies should be carried out to investigate the fusion mechanism with the aim of finding optimal reactions. This problem seems to be most important at this stage of investigations associated with the synthesis of the new elements of the Mendeleev Table.

The authors consider it their pleasant duty to thank Academician G.N.Flerov for his attention and valuable comments at all stages of the work, G.G.Gulbekyan, B.A.Gikal, V.B.Kutner and the U400 cyclotron staff for providing intense heavy ion beams, and N.N.Kolesnikov for helpful calculations. We also thank V.G.Subbotin, V.M.Plotko, A.V.Rykhlyuk for their help in carrying out the experiments and Yu.A.Lazarev, I.I.Zvara and G.M.Ter-Akopyan for interesting discussions.

REFERENCES

1. Oganessyan Yu.Ts. et al. Nucl.Phys., 1975, A239, p.157.
2. Flerov G.N., Ter-Akopyan G.M. Rep.Prog.Phys., 1983, vol.46, p.817.
3. Armbruster P. Int.Conf. on Nucl.Phys., Florence, 1983, vol.2, p.343.
4. Myers W.D., Swiatecki W.J. Nucl.Phys., 1966, 81, p.1; Meldner H. Ark.Fys., 1967, 36, p.593; Nilsson S.G. et al. Nucl.Phys., 1969, A131, p.1.
5. Kharitonov Yu.P. et al. Int.School-Seminar on Heavy Ion Physics, JINR, D7-83-644, Dubna, 1983, p.589.
6. Oganessyan Yu.Ts. et al. Nucl.Phys., 1976, A273, p.305.
7. Munzenberg G. et al. Int.Conf.on Actinides-81, Pacific Grove, 1982, p.223.
8. Munzenberg G. et al. Z.Phys., 1984, A315, p.145.
9. Munzenberg G. et al. XI Int.Workshop on Gross Properties of Nuclei and Nuclear Excitations. Hirschegg, 1983, p.1.
10. Demin A.G. et al. Z.Phys., 1984, A315, p.197.
11. Munzenberg G. et al. Z.Phys., 1984, A317, p.235.
12. Oganessyan Yu.Ts. et al. JINR, E7-84-307, Dubna, 1984.
13. Oganessyan Yu.Ts., Lazarev Yu.A. Heavy Ions and Nuclear Fission. In: Treatise on Heavy Ion Science, 1984, chapter 1, vol.4.
14. Cwiok S. et al. Nucl.Phys., 1983, A410, p.254.
15. Swiatecki W.J. Nucl.Phys., 1982, A376, p.275; Bjornholm S., Swiatecki W.J. Nucl.Phys., 1982, A391, p.471.
16. Flerov G.N. Int.Conf.on Nucl.Phys., Florence, 1983, vol.2, p.365.
17. Ghiorso A. et al. Phys.Rev.Lett., 1974, 33, p.1490.

Received by Publishing Department
on September 25, 1984.

Оганесян Ю.Ц. и др. E2-84-651

Экспериментальные исследования образования и радиоактивного распада изотопов с $Z = 104-109$

С помощью высокочувствительной методики регистрации спонтанного деления ("on-line") и альфа-распада ("off-line") исследовались образование и радиоактивные свойства продуктов реакций "холодного слияния" с $Z = 104-109$. Показано, что все изотопы с $Z = 106-109$, полученные в этих опытах, включая четно-четные изотопы $^{260}106$ и $^{264}108$, испытывают главным образом альфа-распад. Обсуждаются возможности синтеза более тяжелых элементов с $Z > 109$.

Работа выполнена в Лаборатории ядерных реакций ОИЯИ.

Препринт Объединенного института ядерных исследований. Дубна 1984

Oganessyan Yu.Ts. et al. E2-84-651

Experimental Studies of the Formation and Radioactive Decay of Isotopes with $Z = 104-109$

The formation and radioactive properties of "cold fusion" reaction products with $Z = 104-109$ have been investigated using a highly sensitive technique for detecting spontaneous fission ("on-line") and α-decay ("off-line"). It has been shown that all the isotopes with $Z = 106-109$ produced in these experiments, including the doubly-even $^{260}106$ and $^{264}108$, undergo mainly α-decay. Possibilities of synthesizing the heavier elements with $Z > 109$ are discussed.

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

Preprint of the Joint Institute for Nuclear Research. Dubna 1984