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Research Article

Low-energy Nuclear Reactions and Transmutation of Stable and Radioactive Isotopes in Growing Biological Systems

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Abstract

The report presents the results of combined (Mössbauer and mass-spectroscopy) qualifying examinations of stable isotope transmutation processes in growing microbiological cultures, in the iron-region of atomic masses. It is shown that transmutation during the process of growth of microbiological cultures, at optimal conditions in microbiological associations, is 20 times more effective than the same transmutation process in the form of "One-line" (clean) microbiological cultures. In the work, the process of direct, controlled decontamination of highly active intermediate lifetime and long-lived reactor isotopes through the process of growing microbiological associations has been studied. For the first time, an accelerated deactivation rate is observed that is 35 times larger than the controlled deactivation of the Cs^{137} isotope. A theoretical model of low-energy nuclear transmutation in biological objects is discussed also.

Keywords: Isotope transmutation, Low-energy reaction, Microbiological association

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1. Introduction and Foundation of the Effect of Isotopes Transmutation in Biological Systems

The problem of transmutation of stable and active isotopes in biological systems is one of the most mysterious in modern nuclear physics. The hypothesis about the possibility of nuclear transmutation of chemical elements and their isotopes in physical, biological and geological systems with low energy of relative movement of interacting nuclei has been frequently discussed during the last decades [1,2]. Interest toward this issue grew after systematic study of the phenomenon of cold nuclear fusion (CNF) based on dd-reactions in solid systems.

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In our opinion, there are no reasons to consider the process of transformation of isotopes and elements in biological transmutation to be separate and different from the general physical forms of nuclear transmutation that can occur from comparable forms of transformation of isotopes through transmutation, that can occur through alternative processes, governed by the laws of physics. We believe that all the observed isotopic effects (in case they are real and supported by adequate and reliable measurements) can be characterized as the "regular" process of transmutation of isotopes and elements, which occurs in biological systems, and the efficacy of which is determined precisely by the specific characteristics and behavior of such systems.

While analyzing the problem of transmutation of isotopes in growing biological cultures (especially the case of transmutation with generation of isotopes of such chemical elements which are not required by a growing culture in normal conditions) many additional specific questions arise. The most important of them: "Why does a growing culture need this kind of process; How is the process accomplished; Can this process be controlled?"

In the distant future, more refined studies will provide more complete and potentially full and final answers to these questions. The authors recognize the complexities of this problem. Our thesis can be interpreted only as one possible solution, based on our understanding of the problem. Being consistent with our position of objective regularity of such a process, we must note that an explanation ought to be sought among the known laws of physics, chemistry, and biology.

In our opinion, the process of transmutation is evolution's answer to the global dilemma – how is it possible to combine development and adaptation of biological objects, each one of which contains a genetically predetermined set of elements, with a random character and dissimilar distribution of elements in the outer environment, as well as constant environmental changes? This process occurs in places, where there is competition based on the stereochemical analogy (at least in transporting and fermentation systems). The area, where this competition takes place determines the area where transmutation itself is performed. Can we point to a specific spot, or set of conditions, where this ingenious nuclear reaction process takes place? Possibly, there could be many such places or sets of conditions (otherwise, reactions could be such rare events that they would be impossible to detect). Also note, that transmutation occurs with a higher probability in structural parts of biological objects, which are subjected to dynamic influences (zone of growth, non-stationary transport systems, and dynamic response systems to any kind of agitation etc.).

The physical aspects of transmutation processes are related to general problems of low-energy nuclear reactions. Currently, there are over 400 works, in which – with various degrees of agreement and disagreement – different physical models are presented, capable, according to their authors, of explaining the phenomenon of "cold nuclear synthesis," or, at least, of providing a framework for finding ways to explain these kinds of effects. Our point of view with respect to explaining this problem has been presented in our books [1,2]. We think that in the case of dynamic (growing) biological systems, the most effective mechanism, which was suggested [3] and discussed [4] in 1994–1996, is capable of removing – for a brief time – the influence of the Coulomb barrier of a nuclear reaction occurring in a large number of non-stationary potential wells with a structure that is close to being parabolic in volume of any growing biological system. This mechanism will be discussed below.

2. Experimental Investigation of Fusion of Ironregion Stable Isotopes in Optimal Growing Microbiological Associations

About 10–15 years ago we have studied the process of transmutation of stable isotopes in growing "one-line" (one type, "clean") microbiological cultures like *Escherichia coli* or *Saccharomyces cerevisiae* in two kinds of nuclear reactions [4,5]

$$Mn^{55} + d^2 = Fe^{51}, \qquad Na^{23} + P^{51} = Fe^{54}.$$

It was shown that the transmutation process during the growth of such microbiological cultures had taken place, but its effectiveness had been low. Expressed in relative units (defined by the ratio between accumulated number of

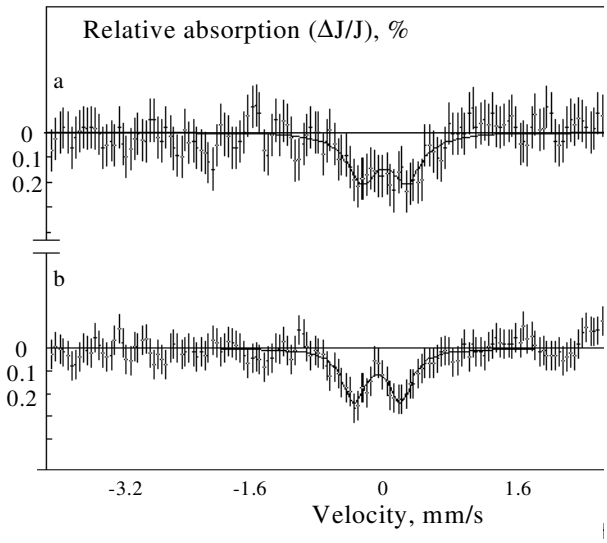

Figure 1. (a) and (b) are Mossbauer spectra of grown identical cultures in different flasks. Culture *Saccharomyces cerevisiae* grown in D_2O in presence of Mn^{55} isotopes.

$N(Fe^{57}$ of Fe^{57} nuclei to the number $N(Mn^{55})$ of Mn^{55} nuclei) the rate (λ) of Fe^{57} production

$$\lambda = N(Fe^{57})/N(Mn^{55})\Delta t \approx 10^{-8}s^{-1}$$

(synthesized Fe^{57} nuclei/s and per single Mn^{55} nucleus) in the case of the reaction with light isotope $Mn^{55} + d^2 = Fe^{57}$, and $\lambda \approx 10^{10}s^{-1}$ in the reaction for the middle range mass isotopes $Na^{23} + P^{31} = Fe^{54}$. The typical Mossbauer spectrum of "one-line" *Saccharomyces cerevisiae* culture, grown in D_2O with the presence of Mn^{55} isotope [1,2,4], is presented in Fig. 1.

The low-relative amplitude of Mossbauer resonance ($\Delta J/J \approx 0.2\%$) in these experiments was the result of low-absolute and relative concentration of created Fe^{57} isotope in the culture. There are two main reasons of low effectiveness of nuclear transmutation in "one-line" microbiological cultures:

- The relatively low efficiency for creating these reactions is the result of the narrow interval of optimal functional individual characteristics for initiating nuclear activity in any "one-line" type of culture. Each of the "one-line" cultures individually requires a set of specific conditions (temperature, hydrogen ion exponent pH, balanced contents of nutrient medium, etc.) for achieving optimal metabolic conditions during the complete period of growth. Such conditions are often absent in real experiments.
- During the growth of a "one-line" culture, we hypothesize that processes involving forms of auto-intoxication of nutrient media by metabolic products take place. This hypothesis is consistent with forms of growth impairment.

In contrast to these "one-line" cultures, during the last year we have investigated microbiological associates that include great numbers of types of different cultures.

The base of "microbial catalyst-transmutator" (MCT) compound that was used is the microbe syntrophic associations of thousands of different kinds of microorganisms that are in the state of complete symbiosis [2,6,7]. These microorganisms appertain to different physiological groups that represent practically the whole variety of the microbe

metabolism and relevantly all kinds of microbe accumulation mechanisms. We postulate that the state of complete symbiosis of the syntropic associations results from the possibility of maximal adaptation of the microorganisms' association in response to changes in any external. These cultures are in a state of natural complete symbiosis and grow as a total correlated multisystem. There are a lot of different types of intraspecific and interspecific stimulated and symbiotic connections between different cultures in the volume of syntrophic associations. This microbiological multisystem adequately reacts to modifications of exterior requirements, to composition of nutrient medium and to biochemical properties of a system because of metabolic growth and transmutation processes. The spectrum of their functional characteristics (including resistance to aggressive environment and methods of synergetic adaptation to this environment) is very wide. We believe that it should be expected that this would lead to high efficiency/effectiveness for stimulating transmutation processes. This model is presented in symbolic form in Fig. 2.

The MCT compound involves special granules that include:

- Concentrated biomass of metabolically active microorganisms (microbe syntrophin association).
- Organic sources of carbon and energy, phosphorus, nitrogen, etc.
- Gluing substances that keep all components in the form of granules stable in water solutions, for a long period of time, subjected to some, possibly many, external conditions.

The general aim of that investigation was to find biotechnology based ways for effective isotope transmutations. The possibility of a potential reaction, $Mn^{55} + d^2 = Fe^{57}$, with heavy water in growing MCT was investigated in the system. This was initiated starting from a more general form of reaction of the form,

"$D_2O + Mn^{55}$ + MCT+ additional isotope components".

The control experiments were conducted in another system

"$H_2O + Mn^{55}$ + MCT+ the same additional isotope components".

A typical series of experiments on nuclear transmutation of isotopes in growing microbiological cultures involved simultaneous growing of separated parts of the same culture in several (usually four) flasks (see Fig. 3).

The first and the second flask contained basic (constant) ingredients: sugar–salt nutrient medium on the basis of light water (H_2O) both with and without $MnSO_4$. In the third flask, the nutrient medium was prepared from the same basic ingredients on the basis of heavy water (D_2O), but without $MnSO_4$. Accordingly, the fourth dish contained nutrient medium with all the ingredients necessary for the culture's growth as well as $MnSO_4$, required for transmutation, and was prepared on the basis of heavy water (D_2O).

From the list of nutrient media, necessary for growing cultures, it can be seen that the isotopic composition necessary for achieving transmutation was in only one (optimized by the isotopic and elementary content) – the fourth flask.

The method of cross-combinations of the nutrient media ingredients has allowed excluding a possible influence of the admixed Fe^{57} isotope on the result of these experiments. In particular, if the Fe^{57} isotope was present, in the form of admixture, in light or heavy water, as part of basic salts, and was also part of the flasks glass, or contained in the air, that isotope would be extracted during the culture's growth and detected in all flasks (including the experiments in flasks 1–3) after growing the culture.

If the Fe^{57} isotope were found only in heavy water, it would be detected in the cultures grown in flasks 3 and 4. If it was present in $MnSO_4$, it would also be detected in the cultures grown in flasks 2 and 4.

Such series of experiments were performed for various cultures, with different growth periods (24, 48, and 72 h) and growth modes. All cultures were grown in the thermostat with the optimal temperature of 32°C. It was discovered, that growing cultures in the media based on heavy water requires continuous stirring of the medium throughout the whole time of growth.

After each series, the substance that was obtained was collected, cleaned in distilled H_2O water and dried. The dried substance in the form of unstructured granules (like peat) were separated using a non-iron containing instrument, ground to a powder and placed in the same amounts in the Mossbauer spectrometer. The mass of the dried biological

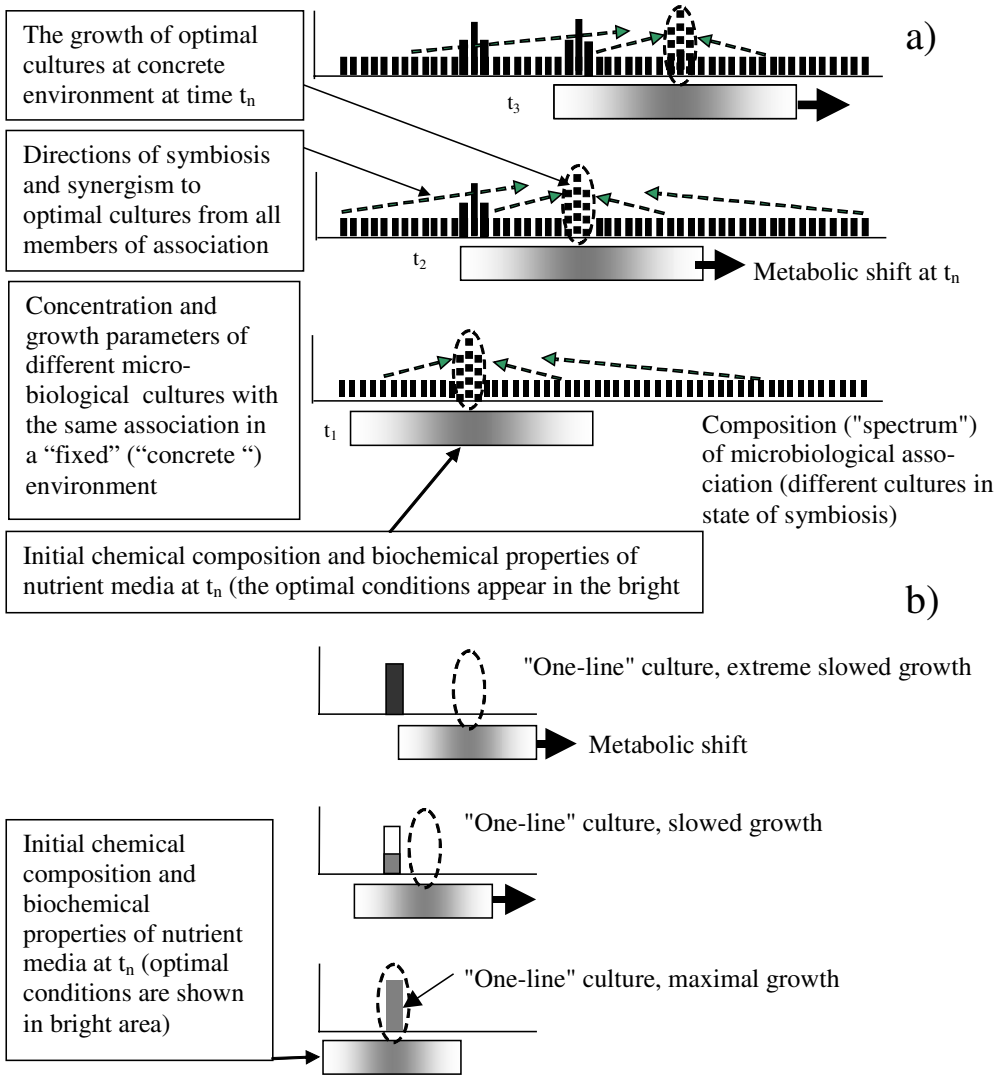

Figure 2. Changes in the directions of symbiosis and synergism in microbiological association (case a) to optimal growing cultures involving changes in types of chemical composition and biochemical properties of nutrient media and environment. Changes in types of optimal cultures is the result of metabolic shifts of chemical composition and biochemical properties of nutrient media. The case (b) presents the process of growth impairment in "one-line" culture with metabolic shifts.

substance, that was investigated, was about 0.3 g.

The results of the Mossbauer measurements of the optimally dried biological substances are presented in Fig. 1 ("one-line" culture) and Fig. 4 (MCT compound (microbiological association)).

In this last experiment with microbiological association, the large amplitude of the Mossbauer resonance

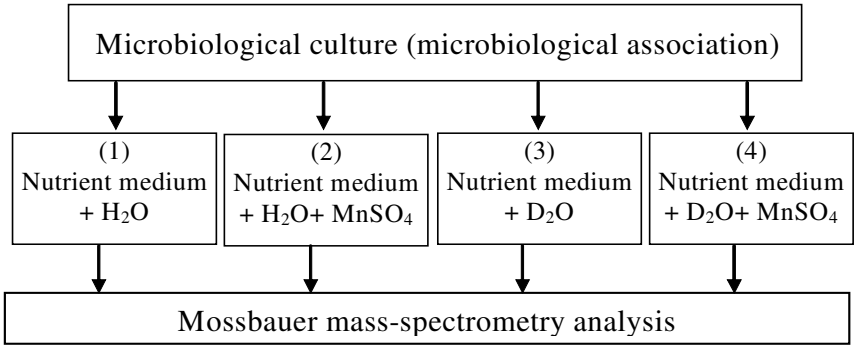

Figure 3. The scheme of "cross-experiments" for studying the effect of nuclear transmutation of isotopes in growing microbiological cultures.

$(\Delta J_{\max}/J_{\text{transmut}}) \approx 3.4\%$) at the same mass of the investigated dried biological substance was observed and measured.

The total, relative number of Fe^{57} nuclei that was created was about 10^{17} nuclei per 1 g of grown and dried biological substances [1,2,7], which is between 10 and 20 times more than the comparable, relative, maximal number of Fe^{57} nuclei that is created in "one-line" grown and dried cultures [1,2,4]. The total mass of Fe^{57} isotopes that is created is about 10^{-5} g per each g of dried biological substance. The efficiency has increased, in particular, because the association has been allowed to grow during a 20 day period. "One-line" cultures cannot be grown for such a long period of time in heavy water because of "self-intoxication" of the medium by the metabolic products (in our former experiments [4] the "one-line" *Escherichia coli* culture was grown during a 72 h period).

The relative efficiency rate λ of such forms of transmutation (the coefficient of transmutation) is the following: $\lambda \approx (0.5 - 1) \times 10^{-6}$ (synthesized Fe^{57} nuclei per s and per single Mn^{55} nucleus) .

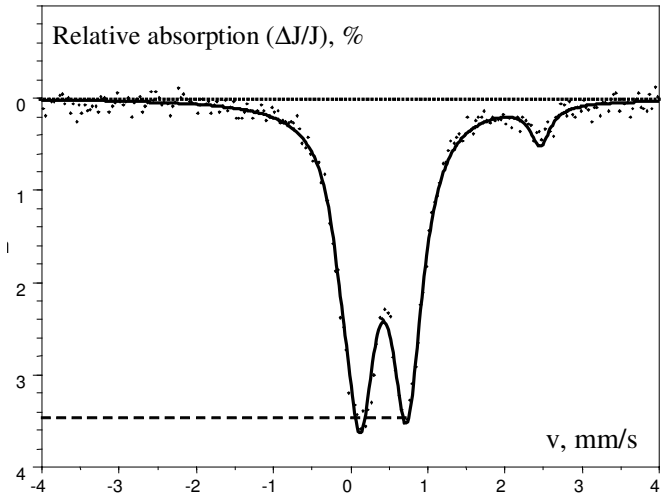

Figure 4. Mossbauer spectra of microbiological MCT grown in nutrient medium in presence of D_2O and Mn^{55} isotope: $\Delta J_{\max}/J \approx 3.4\%$ is the magnitude of the Mossbauer resonance.

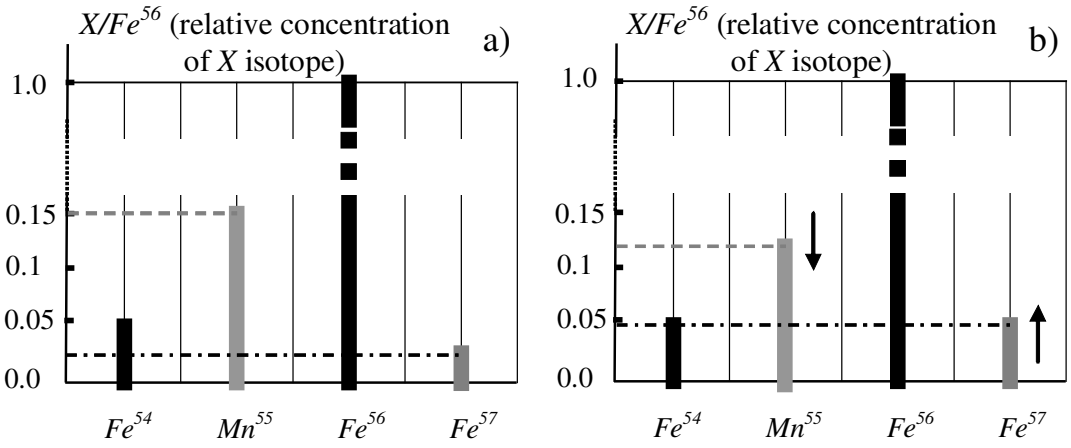

Figure 5. Mass-spectrum of iron-region of microbiological associations (dried biological substances) that were grown in control nutrient medium with H_2O and Mn^{55} (case a) and in experimental nutrient medium with D_2O and the same quantity of Mn^{55} isotope (case b). Here $X = Fe^{54}$; Mn^{55}; Fe^{57} The process of increasing (↑) concentration of Fe^{57} isotopes is accompanied by decreasing (↓) concentration of Mn^{55} isotopes.

For verification of these results, additional examinations of the isotopic ratio of the same dried biological substances (both control and transmutated) were conducted by Thermal Ion Mass Spectroscopy (TIMS), <<Finnigan>> MAT-262.

The results of TIMS measurements presented in Fig. 5 and in Table 1.

The amount of Fe^{57} isotopes that are created are approximately the same in the cases of Mossbauer resonant gamma-spectroscopy and TIMS measurements (concentrations of Fe^{57} isotopes that are created increase by factors of 2–3).

The effectiveness of isotope transmutation during the process of growth of microbiological associations at optimal conditions increases by factors of 10–20 times more than the effectiveness of the same transmutation in “one-line" (clean) microbiological cultures.

The structure and half-width of Mossbauer spectra of control and transmutated microbiological associations are identical. So, the process of transmutation does not appear to change the spatial structure of the growing biological culture. Created and natural Fe are identical in the biochemical sense!

Decrease in the amount of the additional Mn^{55} isotope in the transmutation flask is synchronized with the creation of Fe^{57} isotopes in the same flask. This appears to provide proof of nuclear synthesis in processes associated with a “growing” biological system!

3. Experiments on Controlled Decontamination of Intermediate and Long-Lived Active Isotopes in Biological Cells

Next steps of the investigation were related to the process of direct controlled decontamination of a highly active water mixture of selected different intermediate and long-lived active isotopes by action of the same growing microbiological systems MCT. The process of decontamination (deactivation) of radioactive waste through the action of growth in microbiological systems is connected with transmutation of active nuclei to different non-radioactive isotopes during growth and metabolic processes involving MCT granules.

Table 1. Parameters of mass-spectroscopy investigation of control and transmutated cultures.

Isotope (natural concentration)	Natural isotopic ratio (in relation to Fe^{56})	Concentration in dried biological substance in control experiment: $H_2O + MnSO_4$ + nutrient medium (normalized)	Isotopic ratio in control biological substance	Concentration in dried biological substance in experiment on transmutation: $D_2O + MnSO_4$ + nutrient medium, (normalized)	Isotopic ratio in the experiment on transmutation
Mn^{55}, 100%	--	0.15 ± 0.012	Mn^{55}/Fe^{57} =6.6	0.13 ± 0.012	Mn^{55}/Fe^{57}=7.7
Fe^{56}, 91.7%	1	1	1	1	1
Fe^{57}, 2.2 %	Fe^{56}/Fe^{57}=41.7	0.024 ± 0.002	Fe^{56}/Fe^{57} =42.5	0.051 ± 0.003	Fe^{56}/Fe^{57} =19.5

3.1. Controlled decontamination of intermediate lifetime reactor isotopes

In our work [6], we studied the process of the accelerated decay of activity of reactor water from first contour of water–water atomic reactor of the Kiev Institute of Nuclear Research. The water with total activity about 10–4 Curie/L contained highly active isotopes (e.g., Na^{24}, K^{40}, Co^{60}, Sr^{91}, I^{131}, Xe^{135}, Ba^{140}, La^{140}, Ce^{141}, and Np^{239}).

The spectrum of gamma-radiation of this water is presented in Fig. 6.

For the first time we observed the fast utilization of several kinds of active isotopes to nonradioactive nuclei in the flasks that contained MCT.

The results of the investigation of the time-dependent activity $Q(t)$ of the same reactor Ba^{140}, La^{140} and Co^{60} isotopes in the experiment on transmutation (activity is Q_{cultures}) and in the control one (Q_{control}) are presented in Fig. 7.

For the first time we have observed accelerated utilization (decrease of radioactivity) of radioactive La^{140} and Ba^{140} isotopes in the flasks that contained MCT during the time of the experiment (during 30 days)!

Studied La^{140} isotope has intermediate life-time $\tau_{\text{La}} = 40.3$ h and is a non-stable daughter isotope of Ba^{140} radioactive isotope that has a life-time of about $\tau_{\text{Ba}} = 12.7$ days and the following decay $Ba^{140} \rightarrow La^{140} + \beta^-$.

Initial activities of the Ba^{140} and La^{140} isotopes (on the 10th day after extraction of water from the active zone of the nuclear reactor) were $Q_{Ba^{140}} \approx 1.46 \times 10^{-7}$ Curie / L and $Q_{La^{140}} \approx 2.31 \times 10^{-7}$ Curie / L. A possible path for Ba^{140} isotope transmutation is

$$Ba^{140} + C^{12} = Sm^{152} + \Delta E, \qquad \Delta E \approx 8.5\ \text{MeV}$$

. These reactions are energetically favorable and the reaction energy is positive.

The Sm^{2+} and Ca^{2+} ions are chemically alike and have approximately the same ionic radiuses of divalent state ($R_{\text{Sm}} \approx 1.2$ Å, $R_{\text{Ca}} \approx 1.06$ Å). The substituted element Ca is among several vitally necessary elements. Ions of created Sm^{2+} elements can substitute Ca^{2+} ions while microbiological cultures are growing [1,2]. Probability of such substitution during the process of growing the biological culture is high because the initial concentration of the Ca element in MCT is low.

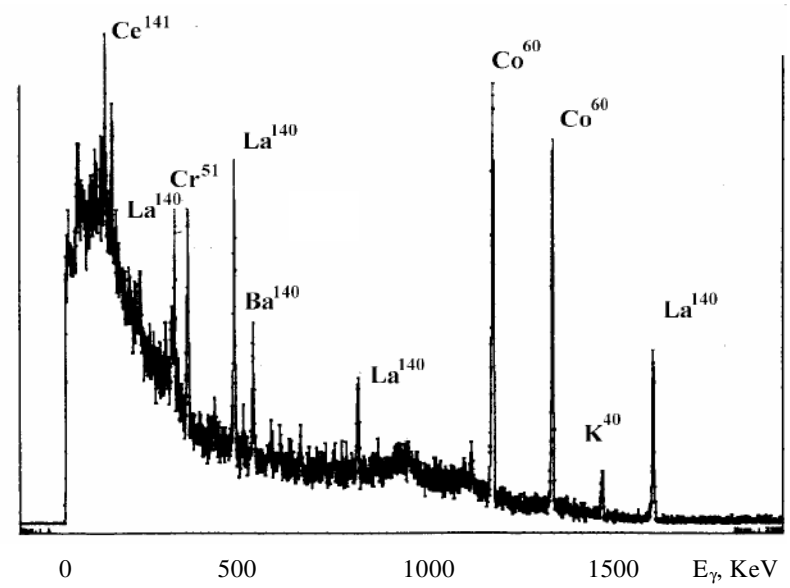

Figure 6. Spectrum of gamma-radiation of distilled water from first contour of water–water atomic reactor 10th day after extraction from the active zone).

3.2. Controlled decontamination of long-lived reactor Cs^{137} isotopes in biological cells

The investigation of controlled decontamination of the long-lived reactor Cs^{137} isotope [7] has been carried out, based on using the identical distilled water but with a process that involves Cs^{137} with an activity of 2×10^4 bq. In the experiments, eight identical closed glass flasks with very thin walls and with 10 ml of the same active water in each were used (see Fig. 8). The MCT compound was placed in seven glass flasks.

In six different flasks, different pure K, Ca, Na, Fe, Mg, and P salts as single admixture were added to the active water. These chemical elements are vitally necessary for any cultures. Each of these specific replacements completely blocks all possible transmutation channels, in which any of the biochemical analogs of the specific chemical element can be used. Two additional flasks were used for control experiments: one flask contained the active water and MCT (but without additional salts) and in another one was only active water (without salts and MCT).

The cultures were grown at the temperature of 20°C. Activity of all closed flasks was measured every 7 days by precise large amplitudes using a Ge detector. The results to show the change of the relative activity $Q(t)/Q(0)$ of the isotopes are presented in Fig. 9 and Table 2.

We have observed increased rates of decay (more precisely accelerated rate of utilization) of Cs^{137} isotopes in all experiments with MCT and in the presence of different additional salts during 100 days! In the control experiment (flask

Table 2. Deactivation of different active isotopes in optimal experiment (MCT + active water with presence of Cs^{137} + $CaCO_3$ salt).

	Start	End of experiments (in 100 days)			
Isotope, energy of gamma radiation	N_1, registered events per 10^3 s	N_2, registered events per 10^3 s	Error (absolute/relative)	Natural decay per 100 days	Change $(N_2\text{-}N_1)/N_2$
Cs^{137}, 661.7 keV	2,66,900	2,16,800	±478(±0.2%)	−0.6 %	−24 %

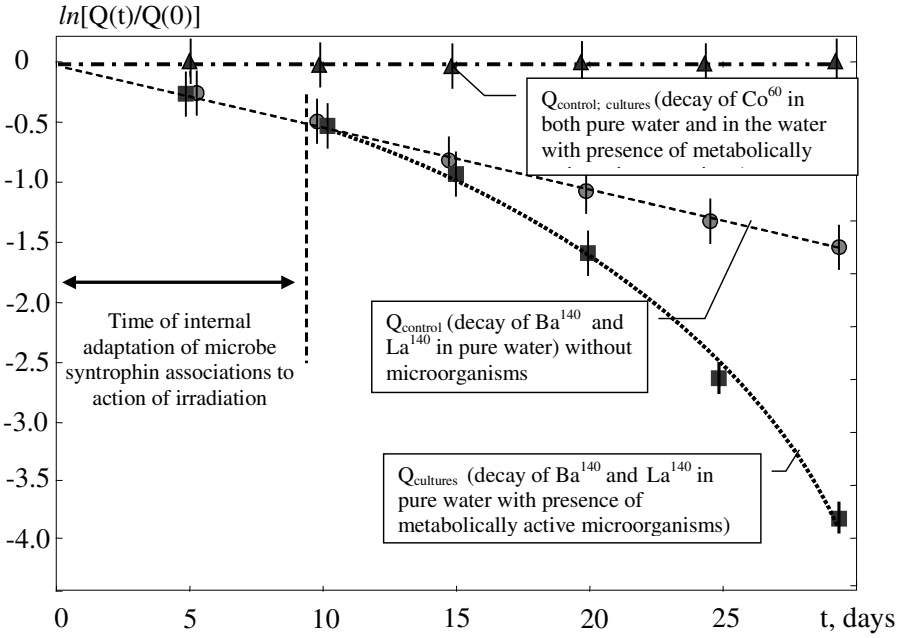

Figure 7. Activity $Q(t)$ of the same reactor Ba^{140}, La^{140} and Co^{60} isotopes in the experiment on transmutation (activity Q_{cultures} in pure reactor water in presence of metabolically active microorganisms) and in the control one (activity Q_{control} in the same pure reactor water without microorganisms). t is the time after extraction of radioactive water from the active zone of reactor.

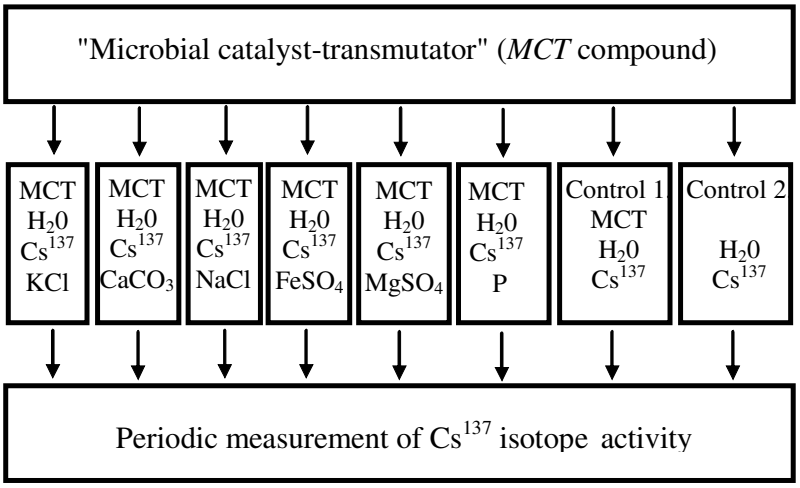

Figure 8. Study of utilization of active isotopes at different conditions.

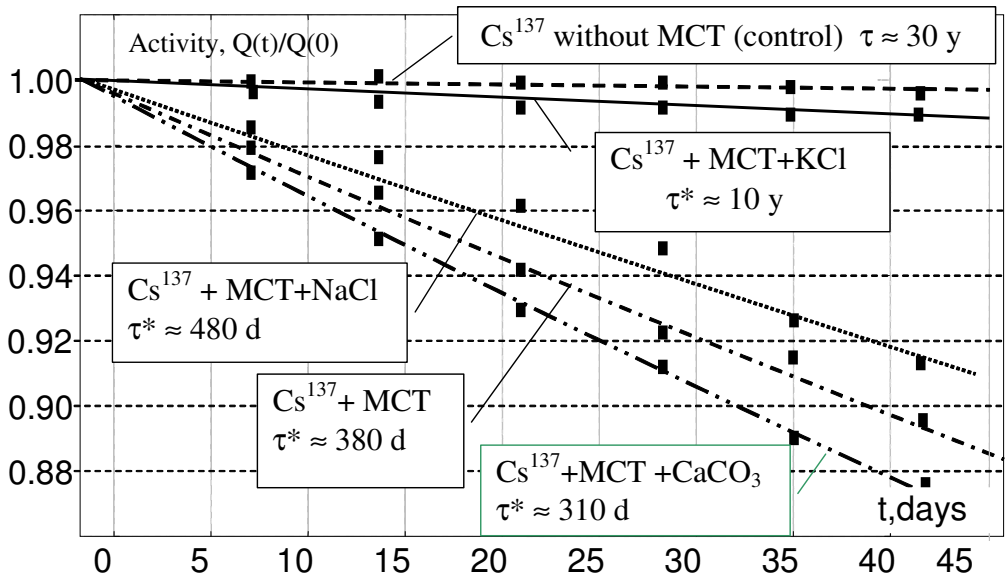

Figure 9. Accelerated deactivation (accelerated rates of decay) of Cs^{137} isotope in "biological cells" in presence of different chemical elements.

with active water but without MCT), the "usual" law of nuclear decay applies, and the life-time was about 30 years. The most rapidly increasing decay rate, which occurred with effective lifetime $\tau^* \approx 310$ days (involving an increase in rate, and decrease in lifetime by a factor of 35 times) was observed in the presence of Ca salt! In the presence of an abnormal (redundant) quantity of potassium in the nutritious media, the process of Cesium transmutation becomes very weak and the life-time of the decay was 10 years.

A possible reaction of radioactive Cs^{137} isotope utilization is

$$Cs^{137} + p^1 = Ba^{138} + 5.5\ \text{MeV}.$$

The result of this reaction is the creation of a stable Ba^{138} isotope.

What is the reason and sense of this reaction for microcultures?

Each metal has its peculiar oxidizing-reconstructive and/or stereochemical analogue among vital microelements, adapted to the particular culture, which are well represented components in microorganisms' metabolism (K^+, Na^+, Mg^{2+} and others). The oxidizing-reconstructive analogy, or redox analogy, implies proximity or parity of redox potentials of reconstructive reactions of a metal and a macro element; stereochemical – proximity or parity of ionic radiuses of a metal and a macro element. One of the consequences of the stereochemical analogy and redox analogy is the non-peculiar nature of interaction of microorganisms with metals. Receptor and transporting and oxidizing-reconstructive systems of a microbial cell make "errors" due to proximity of values of ionic radiuses or redox potentials of a metal and a macro element, and therefore a metal is either accumulated by a microbial cell in a non-peculiar way (by "non-peculiar" we mean accumulation of metals by microorganisms not adapted to them) or it is reconstructed (often with generation of insoluble in water compounds). Some metals are capable of both accumulation and reconstruction by microorganisms. Due to the non-peculiar nature of the aforementioned processes, metals should interact with microorganisms, not adapted to them. Stereochemical analogy presumes proximity or parity of ionic radiuses of a metal and a macro element. Microorganisms react with metals because of this stereochemical analogy.

The Ba^{2+} and K^{+} ions are chemically alike and have approximately the same ionic radius of the associated ionic state ($R_{Ba} \approx 1.4$ Å , $R_K \approx 1.33$ Å). We speculate that substitution of the element K can result in one, among several, vitally necessary elements. Ba^{2+} ions can be created, in principle (as in the last reaction) by substituting elements involving K^{+} ions in metabolic processes while microbiological cultures are growing. This substitution is potentially more effective than the "direct" replacement of Potassium for Cesium because the ionic radius of Cesium is $R_{Cs} \approx$ 1.65–1.69 Å which is larger than the ionic radius of $R_K \approx 1.33$ Å of Potassium. These ions can replace each other in transporting ions through a membrane to a cell (e.g. [8]). A lot is known of such replacements for different ions.

What is the reason for increasing the efficiency of transmutation by increasing the concentrations of calcium? These phenomena are probably connected with general problems of metabolic processes involving microbiological cultures. Optimal growth of microcultures takes place when a balanced relation of micro elements occurs. The phenomenon of low-energy transmutation of chemical elements and isotopes in biological systems and creating conditions for sustaining it is based upon the heuristic proposition that if some of the required elements or microelements are not present in the living environment (or nutrient media), then, given that certain pre-requisites are met, it will be synthesized as a result of the transmutation. In fact, such an approach unambiguously suggests that the ratio of all the necessary elements in each type of living organisms is fixed.

These results reveal a non-trivial nature of interactions of different microelements. By changing the makeup of the nutrient medium, it is possible to control the speed of a culture's growth. Lacking at least one of the microelements in the nutrient medium hinders the development of the entire biological object.

4. The Possible Theoretical Model of Coulomb Barrier Suppression in Dynamical Physical and Biological Systems

To our opinion the process of isotope transmutation in biological systems occurs according to strict laws of physics, but it is induced by certain features of growing biological objects' structure. According to this postulation let us consider briefly the possible mechanisms of nuclei interaction that contribute to effective nuclear transmutation reactions with the formation of Fe^{57} isotope.

It is evident that tunnelling quantum processes can not provide a great probability of nuclear transmutation (e.g. for D_2 molecule the probability of "usual" tunnelling dd-fusion is $\lambda_{d+d} \approx 10^{-70}\,s^{-1}$). We would like to note that all relations for the probability of the tunnel effect have been obtained on the basis of the stationary Schrodinger equation and therefore, relate only to stationary interaction of the nuclei, although the process itself is never stationary. Non-stationary nature of any interaction is evident from the fact that a system of interacting nuclei has its own history and has been formed at some point in the past.

We assume that the most effective action in this case would be the one provided by the mechanism proposed in [3], which is capable of providing a short term elimination of the Coulomb barrier of the pair reaction in dynamical micropotential holes with the structure that is close to parabolic. In such holes the structure of quantum levels is equidistant and is characterized by the spectrum

$$E_n = h\omega_0(n + 3/2), \quad n = 0, 1, 2, \ldots$$

Let the Mn atom be in the center of such a hole. Due to dissociation processes, the hydrophilic compound has a great quantity of free d- deutons (at T =300 K dissociation probability is $\eta \approx 10^{-10}$). When a deuteron gets into the hole due to diffusion, a complex Mn+d appears in the hole. In the free space this complex would correspond to a quasimolecule $(MnD)^{+}$. In the quantum system the situation is more complicated. This complicity is connected to the fact that in such a system the energy of the nucleus interaction $V(r)$ is a sign-variable distance function (see Fig. 10 for a plot of function $r^2V(r)$ which is important for the calculation of diagonal matrix elements).

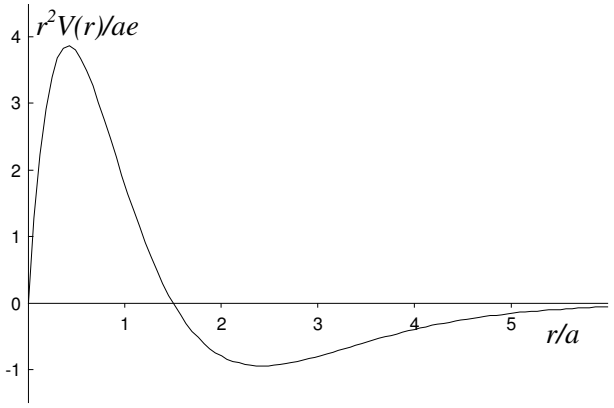

Figure 10. Structure of interaction energy $r^2V(r)$ in Mn–d system.

For distances $r \ll a \equiv h^2/m_e e^2$ the energy $V(r)$ is similar to the energy of the p–e–d system and $V(r) < 0$. In the region of intermediate distances $a/Z \equiv< r < a$ this energy is defined by the Thomas–Fermi approximation

$$V(r) = (Ze^2/r)\xi(rZ^{1/3}/0.885a) \quad \text{and} \quad V(r) > 0.$$

In the region of small distances $r \ll a/Z$ nucleus interaction corresponds to pure Coulomb repulsion of bare nuclei and $V(r) = Ze^2/r > 0$.

Can this energy be a small correction that does not influence the character of nuclei movement in a quantum system? This is the most important question.

According to the first order of non-stationary perturbation theory, to fulfill such condition the diagonal matrix elements $V_{\rm mm}$ of interaction energy should be small and the probability of interlayer transitions

$$W_{\rm nk} = (2\pi/h)^2|V_{\rm nk}(\omega_{\rm nk})|^2 = (2\pi/h)^2|V_{\rm nk}|^2\left\{\frac{\sin(\omega_{\rm nk}\tau/2)}{(\omega_{\rm nk}/2)}\right\}^2$$

caused by this interaction should also be small.

Here

$$V_{\rm nk}(\omega) = \int_{\infty}^{\infty} V_{\rm nk}(t)\mathrm{e}^{i\omega t}\mathrm{d}t,$$

$$V_{\rm nk}(t) = V_{\rm nk}, 0 \le t \le \tau;\ V_{\rm nk} = \int\int\int \Psi_n^*(\vec{r})\hat{V}(\vec{r})\mathrm{d}^3r \equiv 4\pi\int \Psi_n^*(r)V(r)\Psi_k(r)r^2\mathrm{d}r,$$

$$|V_{\rm nk}(\omega)| = |V_{\rm nk}|\left|\frac{\sin(\omega\tau/2)}{(\omega/2)}\right|.$$

The probability of interlayer transition in the regarded parabolic potential becomes equal to zero automatically at the moments $\tau_{\rm s} = 2\pi s/\omega_0$, $s = 1, 2, 3, \ldots$, when frequencies of all possible interlayer transitions $\omega_{\rm nk} = 2\pi s/\omega_0$ correspond to zeroes of the spectral density of perturbation energy $V_{\rm nk}(\omega_{\rm nk}) = 0$ (see Fig. 11)

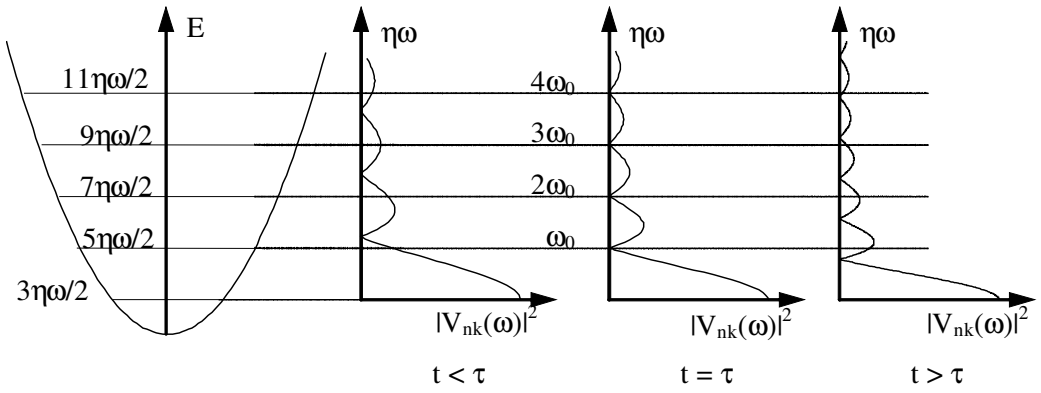

Figure 11. Correlation between energy spectrum of quantum levels E_n and spectral density $|V_{nk}(w)|^2$ of perturbation energy $V(r)$ for short ($t < \tau$), optimal ($t = \tau$) and long ($t > \tau$) duration of $Mn^{55} - d^2$ nuclear interaction.

At such conditions inter-particle interaction completely disappears and the deuteron wave function $\Psi_n(r)$ is determined only by properties of the quantized potential field.

For zeroing of diagonal matrix elements of the interaction energy $V(r)$

$$V_{nn} = 4\pi \int_0^{R_{\text{opt}}} |\Psi_n(r)|^2 V(r) r^2 \mathrm{d}r \to 0.$$

(which is a sign-variable function of inter-nucleus distance) the optimal size R_{opt} of the hole is needed. In [1–4] it was shown that in the case of Mn–d system, $R_{\text{opt}} \approx 4$ Å.

If all above mentioned conditions are satisfied, the independent from Mn quantizing of the deuteron in the hole takes place. In this case the wave function of deuteron $\Psi_n(0)$ in all even states is different from zero in the center of the hole (at $r = 0$), where the Mn nucleus is located. This leads to a high probability of nuclear fusion. The rate of nuclear synthesis (probability of reaction per unit of time for one pair of interacting nuclei) is equal

$$\lambda_{Mn^{55}+d^2} = \Lambda |\Psi_n(r = 0)|^2.$$

Here, $\Lambda = S(E)h/\pi Me^2$ is the constant of nuclear $Mn^{55} - d^2$ interaction; $S(E)$ is the astrophysical nuclear factor depending on a matrix element of the nuclear interaction energy of particles; M is the reduced mass of interacting nuclei. $S(E)$ is the slowly changing function of energy, which is constant $S(E) = S_0$ for low relative energy of interacting particles in the case of non-resonance nuclear reactions.

As can be seen from the given scenario of the process, optimal size and shape of quantizing structures are needed for such non-barrier nucleus interaction. The exact parameters of these structures are very difficult to calculate. The situation substantially improves when the hole parameters are slowly changing, inevitably passing through optimal value. This situation is realized in growing microbiological cultures. During the growth process the replication of DNA, formation of membranes, cells and other bio-molecular objects takes place. In this case in the area of growth inter-atomic potential holes with slowly changing sizes are consistently appearing. If a Mn atom and a deuteron are randomly met in such a changing hole, conditions for a new Fe^{57} isotope fusion will be satisfied.

We hope that the given mechanism satisfactorily describes the basic properties of nuclear transmutation processes, which have been observed in discussed experiments.

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