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Transmutation of stable isotopes and deactivation of radioactive waste in growing biological systems

Vladimir I. Vysotskii [a,*], Alla A. Kornilova [b]

[a] Kiev National Shevchenko University, Vladimirskaya Str., 64, Kiev 01033, Ukraine
[b] Moscov Lomonosov's State University, Moscow 119899, Russia

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ABSTRACT

The report presents the results of qualifying examinations of stable and radioactive isotopes transmutation processes in growing microbiological cultures. It is shown that transmutation of stable isotopes 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" (pure) microbiological cultures. In the work, the process of direct, controlled decontamination of highly active intermediate lifetime and long-lived reactor isotopes (reactor waste) through the process of growing microbiological associations has been studied. In the control experiment (flask with active water but without microbiological associations), the "usual" law of nuclear decay applies, and the life-time of Cs^{137} isotope was about 30 years.

The most rapidly increasing decay rate, which occurred with a 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 closed flask with active water contained Cs^{137} solution and optimal microbiological association.

1. Introduction to the foundation of isotopes transmutation in biological systems

The problem of transmutation of stable and active isotopes in biological systems is one of 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 interacting nuclei has been frequently discussed during the last decades (Vysotskii and Kornilova, 2003, 2009; Biberian, 2012).

The series of works by Kervran (1963, 1966, 1968, 1998) holds a special place in the chronology of transmutation of chemical elements and isotopes in biological objects. In fact, he was the first scientist of the post-nuclear era, who conducted systematic research of possible transmutational processes of chemical elements in biological objects.

This approach, notwithstanding possible accompanying mutual transformation of the nucleons due to weak interaction, does not raise major objections. Moreover, Kervran's perception of the nuclei structure and possible ways of their transformation were very different from customary and contemporary views in nuclear physics.

Interest toward this issue grew after systematic study of the phenomenon of low energy nuclear reactions (LENRs) based on dd-reactions in solid bodies had begun.

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 nuclear transmutation that can occur through alternatived processes, controlled 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 whose effectivity 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 those chemical elements which are not required by a growing culture in normal conditions) many additional specific questions arise. The most important of them: "Why a growing culture needs this kind of process?; How is this 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 all complexity of this problem. Our thesis, which is outlined below, can be interpreted only as a possible solution, based on our understanding of the problem. Being consistent with our position of objective regularity of such a process, we must

* Corresponding author.
E-mail address: vivysotskii@gmail.com (V.I. Vysotskii).

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note that an explanation has to be sought among the known laws of physics, chemistry and biology.

In our opinion, the process of transmutation is the 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 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, dynamic response systems to any kind of agitation, etc.).

The physical aspects of transmutation processes in growing microbiological cultures are related to general problems of low-energy nuclear reactions. Currently, now there are over 500 works, in which – with various degrees of agreement and disagreement – different physical models are presented, which are 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 (Vysotskii and Kornilova, 2003, 2009) and published in works (see Vysotskii and Adamenko, 2010, 2012; Vysotskii et al., 2012a,b). This universal mechanism of optimization of low energy nuclear reactions is connected with formation of correlated states of interacting particles. We have considered the preconditions and the methods of formation of a correlated coherent state of nuclei in real dynamical (non-stationary) systems. This mechanism gives rise to the giant increase of Coulomb barrier penetrability (by 20...100 and more orders of magnitude) under conditions, very far from optimal (very low energy, high barrier), where the effectiveness of tunneling effects is negligibly small.

2. Experimental investigation of fusion of iron-region stable isotopes in optimal growing microbiological systems

Since 1994–1995 we have studied the process of transmutation of stable isotopes in growing "one-line" (one type, "pure") microbiological cultures in two nuclear reactions (Vysotskii et al., 1996, 2000, 2001)

$$Mn^{55} + d^2 = Fe^{57}, \quad Na^{23} + P^{31} = Fe^{54}$$

Experiments were conducted using several bacterial cultures (*Bacillus subtilis*, *Escherichia coli*, *Deinococcus radiodurans*) as well as the yeast culture *Saccharomyces cerevisiae*. Selection of these cultures was motivated either by their experimentally proven ability to grow in the heavy water based media or by the prospect of using the radiation-stable culture *D. radiodurans* in transmutation processes within strong radiation fields, as was noted earlier.

2.1. Study of isotopic transmutation in microbiological cultures using the Mössbauer spectrometry method

The first series of experiments on biological transmutation of isotopes in reaction $Mn^{55} + d^2 = Fe^{57}$ were carried out provided the possibility of investigating the results of the transmutation by several independent methods. These experiments were based on the expected synthesis reaction of the Mössbauer isotope Fe^{57} in a microbiological culture, that grows in the iron-poor water-salt nutrient medium based on the heavy water D_2O containing manganese salt. Among the undisputable advantages of using manganese is its single stable isotope Mn^{55}.

This circumstance makes interpretation of experimental results unambiguous.

The result of the expected synthesis reaction is formation of a rare stable isotope Fe^{57}, concentration of which in natural iron is very small and equals 2.2%.

A typical series of experiments included several consecutive steps. The culture, preliminary treated in a centrifuge, thoroughly rinsed in distilled light water (H_2O), and being bred in a stimulating environment, was placed in a dish with controlled salt–sugar nutrient medium, containing basic (present both in trial experiments and experiments on transmutation) salts of Mg, Ca, K, ammonium tartrate, sucrose, and 10 ml of pure water (heavy water D_2O in experiments on transmutation, and light water H_2O in trial experiments).

Fig. 1a shows the Mössbauer spectrum for the culture *S. cerevisiae*, grown for 72 h in the optimal nutrient media, containing the necessary ingredients for achieving transmutation (D_2O and $MnSO_4$).

It can be seen, that in the spectrum there are clear signs indicating the presence of the Mössbauer Fe^{57} isotope. The total mass of the grown culture in each of the experiments was equal to 0.3–0.5 g. Spectrum 1b corresponded to the same culture *S. cerevisiae*—grown in flask 2—containing the medium based on light water with the presence of $MnSO_4$, and spectrum 1c also related to the same culture grown in flask 3 (medium based on heavy water D_2O, without adding $MnSO_4$ salt). It follows from these spectrums, that the amount of Fe^{57} isotope in cultures grown in non-optimal mediums matches the background level and lies below the level of detection.

The final values for the relative depth of absorption resonance, the total number of nuclei of the synthesized Fe^{57} isotope and the mass of these nuclei are, respectively:

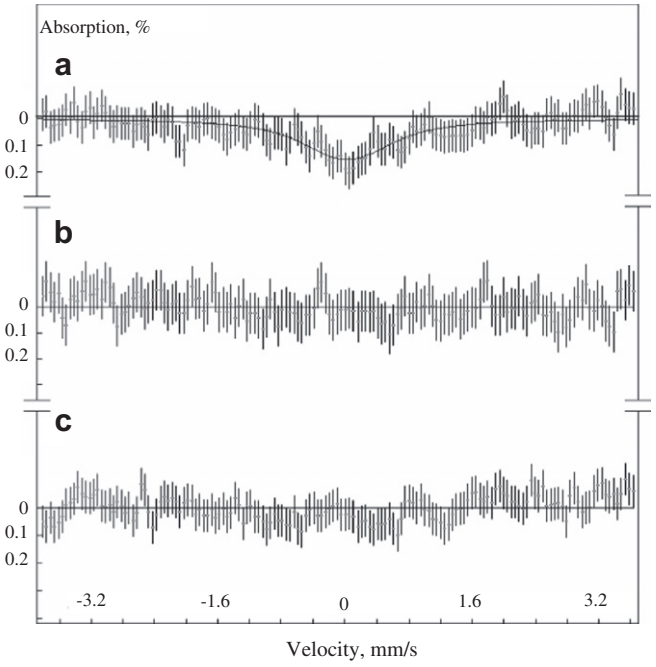

Fig. 1. The Mössbauer spectrum for the grown culture *Saccharomyces cerevisiae*: (a) in D_2O with Mn^{55}; (b) in H_2O with Mn^{55}; (c) in D_2O without Mn^{55}.

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$\eta_{Fe^{57}} = (1.9 \pm 0.53) \times 10^{-3}$, $N_{Fe^{57}} = (0.87 \pm 0.24) \times 10^{16}$,
$m_{Fe^{57}} = (1 \pm 0.28) \times 10^{-6}$ g

The transmutation coefficient, corresponding to the detected reaction of low-temperature synthesis, is given by

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

(nuclei of the synthesized Fe^{57} isotope, counting for 1 s and only nuclei of Mn^{55} isotope).

Similar results were obtained in the process of growth of other cultures in optimal conditions.

2.2. Study of controlled transmutation of isotopes with middle range atomic numbers in a growing microbiological culture using the laser time-of-flight mass-spectrometer

Experiments on monitoring and research of the phenomenon of nuclear low-temperature transmutation of isotopes with middle-ranged atomic numbers were based on the expected synthesis reaction

$$Na^{23} + P^{31} = Fe^{54}$$

in a growing microbiological culture placed in an optimized nutrient medium, with deficit of iron, but additionally containing controlled quantities of single-isotope chemical elements Na^{23} and P^{31}. This reaction is characterized by a positive energy release

$$Q = [M(Na^{23}) + M(P^{31}) - M(Fe^{54})]c^2 = 22.4\ \text{MeV}$$

and, therefore, can run with any energy of interacting isotopes (including close to zero energy of relative motion). The main problem here is, naturally, breaking the Coulomb's barrier. It will be examined in another paper. Research was conducted on the bacterial culture *B. subtilis*.

The result was the creation of the rare isotope Fe^{54}, whose concentration in natural iron is small and equal to $\eta = 5.8\%$. An obvious advantage of this reaction (much like the synthesis reaction of the rare Mössbauer isotope Fe^{57}) is the stability of its final product, its low concentration in natural iron and ability to accumulate in the culture volume during its growth. It can be easily detected with the help of mass spectrometry.

The following experimental methodology was used.

A prepared culture, after being treated in a centrifuge, rinsed with water and preliminary bred, was placed in pans with sugar–salt nutrient medium containing salts of Mg, Ca, K, Na, sucrose and 100 ml of distillated light water H_2O. The culture was grown in a thermostat at the temperature of 32 °C, optimal for growth.

The main idea of the experiments was growing cultures in several alternative nutrient mediums, among which only one containing both Na^{23} and P^{31} isotopes was required for a synthesis reaction. For this purpose, K_2HPO_4 was added to the nutrient medium containing, among other substances $NaNO_3$, in the experiment on transmutation.

A typical series of measurements of mass spectra consisted of three consecutive main operations:

- Measuring the mass spectrum of pure natural iron (the basic experiment for obtaining the basic benchmark mass spectrum of all natural iron isotopes).
- Research of the mass spectrum of the reference desiccated culture, grown in the medium with all ingredients (including Na^{23} isotope contained in $NaNO_3$), but without the P^{31} isotope (i.e., without K_2HPO_4).
- Research of the mass spectrum of a desiccated culture grown in the medium with all ingredients with the presence of Na^{23} and P^{31} isotopes.

Prior to the making measurements and creating vacuum, the studied objects were placed in the same vacuum camera of a laser mass spectrometer. All samples were placed in open separated microcavities, with surface made of a high-purity lead plate, which were open from the side of laser impulse exposure, with a diameter greater than the cross section of the focal point of the laser. The adjusting system of the mass-spectrometer could move this plate inside the vacuum chamber and place each of the micro-cavities on the point coinciding with the focal point of laser impulse. After each sample has been subjected to laser impulse impact, a cloud of dispersing laser plasma with a temperature of about 100 eV was formed. After achieving extraction of monoenergetic ions from plasma (using an energetic discriminator with narrow energetic window) and subsequent fly-through selection, plasma ions were separated according to their mass. After detection, processed electronic signals were sent to a double beam oscillograph with memorizing capacity with subsequent storing on photographic film or inside a data storing and processing system.

First, an analysis of the entire mass spectrum was conducted, and then separate isotopes were investigated in more detail.

Reliability and presentation of recording measurement results were given special attention. The most clearness was achieved with photographing mass spectrums of isotopes on the double-beam oscillograph with memory. Registration of isotopes' distribution was accomplished in the form of a sequence of paired series of measurements.

Each one of those paired series initially included obtaining the basic (benchmark) spectrum for natural iron isotopes, which was formed by influencing micro-cavities containing iron by laser impulse. The basic spectrum was then recorded in the form of a laser-synchronized upper beam sweep on the screen of the double beam oscillograph.

After that, the micro-cavity with a sample of an investigated culture was moved to the area of laser focal point and a spectrum of isotopes of that culture was obtained. That spectrum was recorded on the same screen of the double-beam oscillograph in the form of the lower beam sweep, which was fully synchronized with the upper beam sweep representing the basic spectrum of natural iron. After that, obtained spectrums were photographed from the screen of the oscillograph.

The same spectrums were independently registered on a computer.

The photographs Fig. 2 are made from the screen of a multibeam oscillograph with memory and show the mass spectrum of the basic and control samples, as well as the samples, which were subjected to the process of transmutation. The upper beam sweep (upper curve) on all figures corresponds to the spectrum for natural iron (the basic experiment) with peaks of Fe^{54} (left) and Fe^{56} (right), and the lower beam sweep—to the spectrum of a studied culture (control or transmutation experiments). It can be seen from the photographs, that in the spectrums of each of the studied cultures there is a minor shift of the ion current peak corresponding to different isotopes to the left (i.e., towards lower masses), relative to the position of corresponding natural iron isotopes in each spectrum. This shift is related to the specifics of the time-of-flight spectrometer, determined by special features of movement and interaction (a slight repulsion) of ionic clots, corresponding to different elements in the process of their separation and consequent movement. The influence of the plasma package of heavy ions of lead, which, repulsing the ions of lighter elements and isotopes, slightly shift them on their trajectory, causing thus their earlier detection, is mainly responsible for such additional shifting of ion clots.

Evident from the photographs and diagrams is a very large increase of absolute and relative concentration of rare isotope Fe^{54} for the culture grown in the optimal nutrient medium. This

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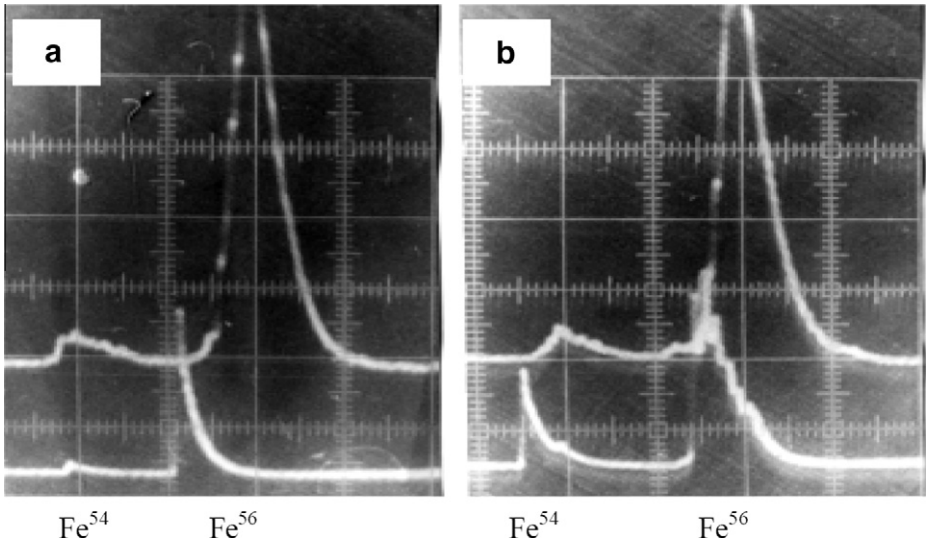

Fig. 2. Photographs from the screen of the oscillograph, representing the mass spectrum in the area of isotopes of iron. The upper graphs show the basic (benchmark) experiment for pure natural iron; the lower graphs show the mass spectrum of grown microbiological culture. left photo (a) – controlling experiment (culture grown in a medium without isotope P^{31}, right photo (b) – transmutation experiment (culture grown in a medium in the presence of isotopes P^{31} and Na^{23}).

increase corresponded to deviation of concentration ratio of isotopes from the natural value

$$\eta(Fe^{54})/\eta(Fe^{56}) \approx 0.06$$

(for natural iron in the basic experiment and rare admixed natural iron in the controlling experiment) to the value

$$\eta^{*}(Fe^{54})/\eta(Fe^{56}) \approx 0.20\text{–}0.25$$

(for the experiment on transmutation in the optimal medium).

Transmutation coefficients, averaged by several series of measurements, in the reaction $Na^{23} + P^{31} = Fe^{54}$ are given by

$$\lambda_P = N(Fe^{54})/N(P^{31})\Delta t = \{\eta(Fe^{54})/\eta(Fe^{56})\}N(Fe^{56})/N(P^{31})\Delta t \approx (3\text{–}6) \times 10^{-10}\ s^{-1}$$

(nuclei of synthesized isotope Fe^{54} counting for 1 s and only nuclei of P^{31} isotope),

$$\lambda_{Na} = N(Fe^{54})/N(Na^{23})\Delta t = \{\eta(Fe^{54})/\eta(Fe^{56})\}N(Fe^{56})/N(Na^{23})\Delta t \approx (1\text{–}2) \times 10^{-10}\ s^{-1}$$

(nuclei of synthesized isotope Fe^{54} counting for 1 s and only nuclei of Na^{23} isotope).

2.3. Effective nuclear fusion and transmutation of stable isotopes in microbe syntrophin associations

The low relative amplitude of Mössbauer 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.

Contrary to these "one-line" cultures, during last years we have investigated microbiological associates that include a great number of types of different cultures.

The base of MCT ("microbial catalyst-transmutator") compound that was used is the microbe syntrophin associations of thousands different microorganism kinds that are in the state of complete symbiosis (Vysotskii et al., 2003b; Vysotskii et al.,2008; Vysotskii and Kornilova, 2009). 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 syntrophin associations results from the possibility of maximal adaptation of the microorganisms' association in response to changes in any external condition. 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 syntrophin 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 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 many, possibly any, external conditions.

The general aim of that investigation was to find biotechnology-based ways for effective isotope transmutation. 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,

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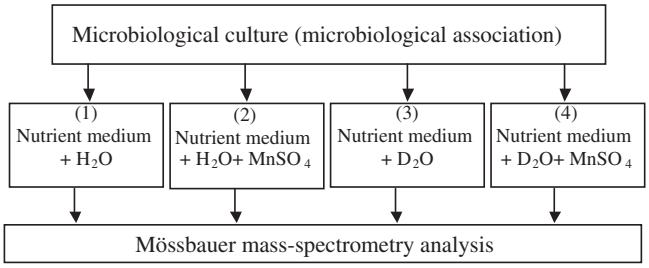

Fig. 3. The scheme of "cross-experiments" for studying the effect of nuclear transmutation of isotopes in growing microbiological cultures.

"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 elemental content)—the fourth flask.

The method of cross-combinations of the nutrient media ingredients has allowed to exclude a possible influence of the admixed Fe^{57} isotope on the result of these experiments. In particular, if the Fe^{57} isotope were present, in the form of admixture, in light or heavy water, as part of basic salts, and was also part of the flask's glass, or contained in the air, that isotope would be extracted during the culture's growth and detected in all flask (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 similar MCT, with different growth periods (typically 20–24 days) 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 Mössbauer spectrometer. The mass of the dried biological substance that was investigated was about 0.3 g.

The results of Mössbauer investigation of both control and optimal dried biological substances are presented in Figs. 4 and 5.

In these experiments different amplitudes of Mössbauer resonance ($\Delta J/J \approx 1.05\%$) and ($\Delta J/J \approx 3.4\%$) at the same masses of investigated dried biological substances were observed and measured. It is well known that the amplitude of Mössbauer resonance is proportional to the concentration of resonant nuclei (if this concentration is low).

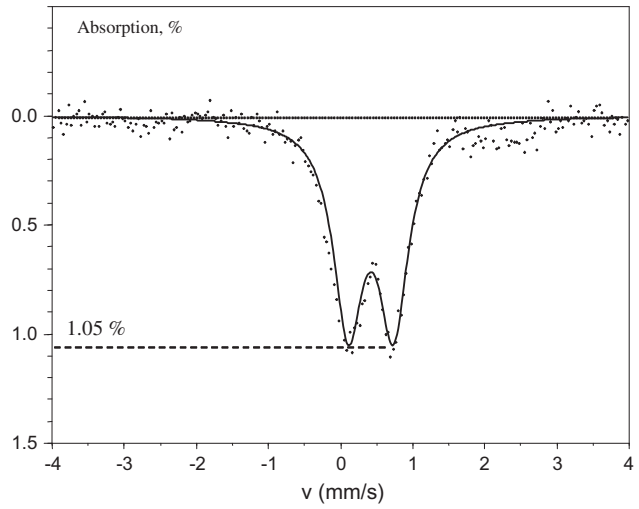

Fig. 4. Mössbauer spectrum of microbiological MCT grown in the volume with presence of H_2O and Mn^{55} isotope (control): $\Delta J_{max}/J \approx 1.1\%$ is the magnitude of Mössbauer resonance.

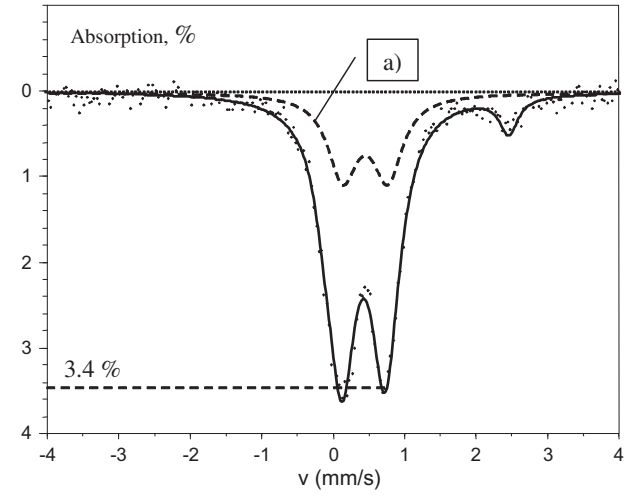

Fig. 5. Mössbauer spectrum of microbiological MCT grown in the volume with presence of D_2O and Mn^{55} isotope (experiments on transmutation): $\Delta J_{max}/J \approx 3.4\%$ is the magnitude of Mössbauer resonance. (a) – Mössbauer spectrum from Fig. 4 (control).

Registration of Mössbauer Fe^{57} isotope in the biological substance that was grown in non-optimal medium (see Fig. 4 for the control experiment) is the result of presence of natural Fe as admixture in the components of initial MCT compound.

The total relative number of Fe^{57} nuclei that was created is about 10^{17} nuclei per 1 g of grown and dried biological substances (Vysotskii and Kornilova, 2009; Vysotskii et al., 2008), which is between 10 and 20 times more than the comparable relative maximum number of Fe^{57} nuclei that is created in "one-line" grown and dried cultures (Vysotskii and Kornilova, 2003, 2009). 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 experiments (Vysotskii et al., 2001) the "one-line" *E. coli* culture was grown during a 72 h period).

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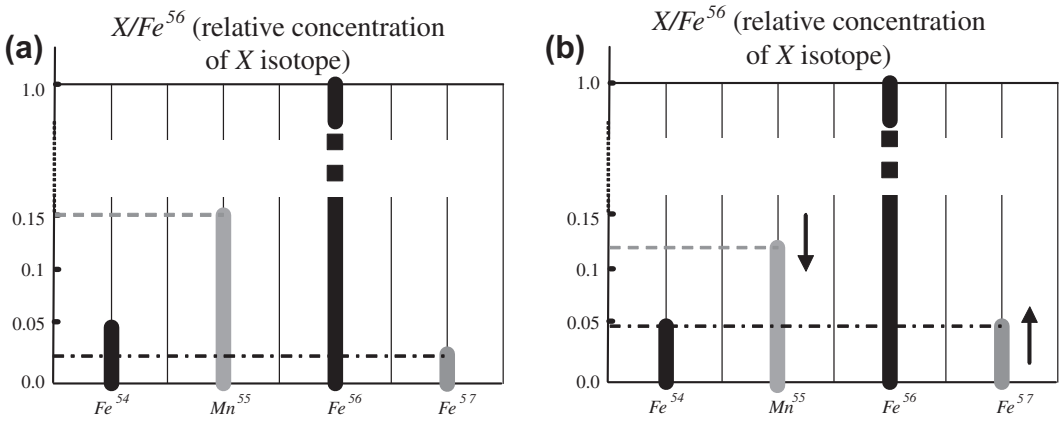

Fig. 6. Mass-spectrum of iron-region of microbiological associations (dried biological substances) that were grown in control nutrient medium with H_2O and Mn^{55} (case a)) and in experimental nutrient medium with D_2O and the same quantity of Mn^{55} isotope (case b)). Here $X = Fe^{54}$; Mn^{55}; Fe^{57}. The process of increasing (↑) of concentration of Fe^{57} isotope is accompanied by decreasing (↓) of concentration of Mn^{55} isotope.

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%	$Mn^{55}/Fe^{57} = 7.7$	–	0.15 ± 0.012	$Mn^{55}/Fe^{57} = 6.6$	0.13 ± 0.012
Fe^{56}, 91.7% Fe^{57}, 2.2%	1 $Fe^{56}/Fe^{57} = 41.7$	1 0.024 ± 0.002	1 $Fe^{56}/Fe^{57} = 42.5$	1 0.051 ± 0.003	1 $Fe^{56}/Fe^{57} = 19.5$

The relative efficiency rate λ of such forms of transmutation (the coefficient of transmutation) is the following:

$\lambda \approx (0.5\ldots1) \times 10^{-6}$ (synthesized Fe^{57} nuclei per *s* and per single Mn^{55} nucleus).

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

The results of TIMS measurements presented in Fig. 6 and in Table 1.

The amounts of Fe^{57} isotopes that are created are approximately the same in the cases of Mössbauer 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" (pure) microbiological cultures.

The structure and half-width of Mössbauer 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!

Decreases in the amounts of the additional Mn^{55} isotope in the transmutation flask are synchronized with the creation of Fe^{57} isotopes in the same flask. This appears to provide proof (a "form of acknowledgement" or a "footprint") of nuclear synthesis in processes associated with a "growing", biological system!

3. Experiments on controlled decontamination of intermediate and long-lived active isotopes (reactor waste) in microbiological cells

Next steps of 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.

3.1. Controlled decontamination of intermediate lifetime reactor isotopes

In our work (Vysotskii et al., 2003b) we studied the process of accelerated decay of activity of reactor water from first contour of water–water atomic reactor of 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}, Np^{239}).

The spectrum of gamma-radiation of this water is presented in Fig. 7.

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

The results of investigation of the time-dependent activity $Q(t)$ of the same reactor Ba^{140}, La^{140} and Co^{60} isotopes in the experi-

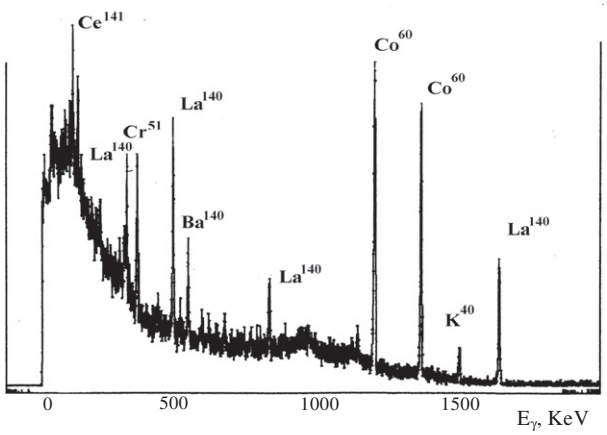

Fig. 7. Spectrum of gamma-radiation of distilled water from first contour of water–water atomic reactor (10th day after extraction from the active zone).

ment on transmutation (activity is Q_{cultures}) and in the control one (Q_{control}) are presented in Fig. 8.

For the first time we have observed accelerated deactivation of radioactive La^{140} and Ba^{140} isotopes in the flasks that contained MCT during all time of experiment (during 30 days)! Studied La^{140} isotope has intermediate life-time $\tau_{La} = 40.3$ h and is nonstable daughter isotope of Ba^{140} radioactive isotope that has life-time about $\tau_{Ba} = 12.7$ 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 radioactive Ba^{140} isotope transmutation to the stable state is

$$Ba^{140} + C^{12} = Sm^{152} + \Delta E$$

These reactions are energy favorable and the energy of reaction is positive:

$$\Delta E = E(A_{Ba}Z_{Ba}) + E(A_C Z_C) - E(A_{Sm}Z_{Sm}) \approx 8.5 \text{ MeV}$$

The Sm^{2+} and Ca^{2+} ions are chemically alike and have the approximately the same ionic radiuses of divalent state ($R_{Sm} \approx 2.2$ A°, $R_{Ca} \approx 1.06$ A°). The substituted element Ca is among

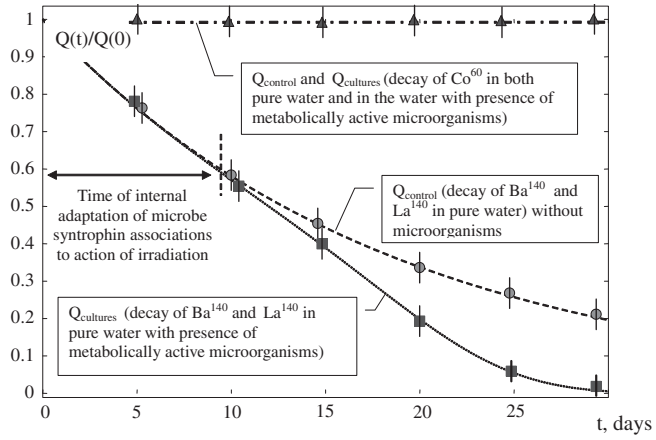

Fig. 8. Activity $Q(t)$ of the same reactor Ba^{140}, La^{140} and Co^{60} isotopes in the experiment on transmutation (activity Q_{cultures} in pure reactor water with presence of metabolically active microorganisms) and in the control one (activity Q_{control} in the same pure reactor water without microorganisms). t – time after extraction of radioactive water from the active zone of reactor.

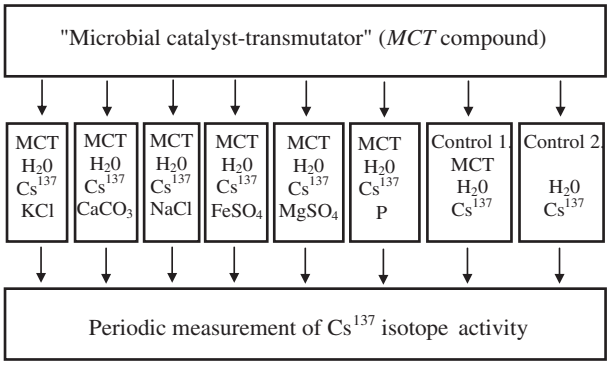

Fig. 9. Study of deactivation of active isotopes at different conditions.

several vitally necessary elements. Ions of created Sm^{2+} elements can substitute Ca^{2+} ions while microbiological cultures are growing (Vysotskii and Kornilova, 2003, 2009). Probability of such substitution during process of growing of biological culture is high because the initial concentration of Ca in MCT is low.

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

It is well known, that the Cs^{137} isotope is the most dangerous long-lived component of spent reactor fuel. Investigating the possible ways of deactivation of this isotope is very important.

The process of decontamination (deactivation) of radioactive waste through the action of growth in microbiological systems is connected with transmutation of long-lived active nuclei to different non-radioactive isotopes during growth and metabolic processes involving MCT granules.

The investigation of controlled decontamination of long-lived reactor Cs^{137} isotope (Vysotskii et al., 2004) has been carried out, based on the use of identical distilled water but with a process that involves Cs^{137} with an activity of 2.10^4 bq. In the experiments, 8 identical closed glass flasks with very thin walls and with 10 ml of the same active water in each were used (see Fig. 9). The MCT compound was placed in 7 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 culture. Each of these specific replacements completely blocks all possible transmutation channels, in which any biochemical analog 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 the other there was only active water (without salts and MCT).

The cultures were grown at the temperature 20 °C. Activity of all closed flasks has been measured every 7 days precisely by use of a Ge detector.

The results of investigation of change of relative activity $Q(t)/Q(0)$ of isotopes are presented in Table 2 and Fig. 10.

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

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

	Start	Finish 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 day	Change $(N_2-N_1)/N_2$
Cs^{137}, 661.7 keV	266,900	216,800	±478 (±0.2%)	−0.6%	−24%

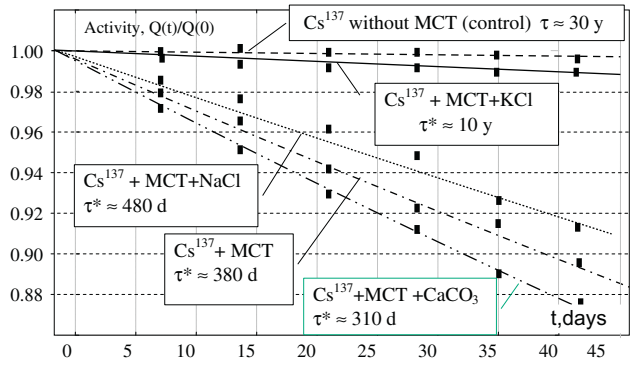

Fig. 10. Accelerated deactivation (accelerated rates of decay) of Cs^{137} isotope in "biological cells" in presence of different chemical elements.

sium transmutation becomes very weak and the life-time of the decay was about 10 years.

A possible reaction of Cs^{137} isotope deactivation is

$$Cs^{137} + p^1 = Ba^{138} + \Delta E.$$

The result of this reaction is the creation of a stable Ba^{138} isotope. This reaction is energetically favorable (ΔE = 5.58 MeV is positive).

The Ba^{2+} and K^+ ions are chemically alike and have approximately the same ionic radii 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 vitally necessary element. Ba^{2+} ions can be created, in principle, (as in the last reaction) by substituting elements involving K^+ ions in metabolic process 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 Potassium. These ions can replace each other in transporting ions through a membrane to a cell (Van Brunt et al., 1982; Vysotskii and Kornilova, 2003, 2009).

Which is the reason for increasing the efficiency of transmutation by increasing the Ca concentration?

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), and if 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 of just one microelement in the nutrient medium hinders the development of the entire biological object.

4. Conclusions

The above examples show that the effect of low temperature transmutation of isotopes may be used in solving a very wide array of tasks—from issues of life support and forming a new perspective on human pathogenesis to the problem of deactivation of spent nuclear fuel. Consistent application of the ideology of transmutation of isotopes and chemical elements in living organisms may lead to re-evaluation of a wide spectrum of issues concerning functioning of live organisms (including cases of absence of some vital macro and micro-elements in the environment in extreme conditions).

The problem of synthesis of rare and very rare isotopes, many of which cannot yet be used, due to very limited quantity and very high cost, has also a great importance. Due to the possibility of local synthesis of required isotopes in a predetermined location, new solutions to problems of modern technology (for example, modern integral microelectronics and molecular nanotechnology), could be found, possibly leading to very unexpected results.

The use of processes of low energy transmutation of radioactive isotopes in biological systems (including deactivation of those major and most dangerous reactor isotopes like Cs^{137}) may provide the main foundation for eliminating the most debatable aspects in existing technologies, associated with processing spent nuclear fuel, and offer new solutions to problems, which could not be resolved by traditional methods of chemical technologies.

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