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Research Article

"Biological Transmutation" of Stable and Radioactive Isotopes in Growing Biological Systems

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Abstract

The prehistory, present state and prospects of transmutation of stable and radioactive isotopes in growing biological objects are considered. The biological and physical causes of this phenomenon are briefly considered. It is shown that the most likely physical mechanism for the production of nuclear reactions in biological systems is the process of formation of coherent correlated states of interacting particles. This process is accompanied by giant energy fluctuations, which can exist for a long time, sufficient to produce nuclear reactions. This process happens automatically in non-stationary potential wells, which are formed during cell division, DNA replication, at the entrance to plasma ion channels and in other places of growing objects.
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1. Introduction

The phenomenon of "biological transmutation of isotopes" is one of the most interesting, controversial and mystifying phenomena of both physics and biology. Its roots are associated with alchemy, and the current state is connected, on one hand with modern genetics and physiology, and on the other hand with the most advanced directions of nuclear physics, quantum mechanics and electrodynamics. This problem has been discussed many times in recent decades and has many supporters, and even more opponents. A brief background of this phenomenon is presented and discussed in [1–8]. A particularly large contribution to the prehistory of this problem was made by Louis Kervran [3–6], who very actively propagated his own experimental studies devoted to the possibility of producing nuclear transmutations of different chemical elements in various biological systems (both among plants animals and microorganisms).

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In particular, Kervran investigated the reaction of potassium transmutation in calcium $K^{39} + p^1 \rightarrow Ca^{40}$ in a biological system containing hydrogen. He also investigated many other reactions of isotope transmutations, among which one should especially note those that lead to the formation of vital micro-nutrients (Fe, Mn, Zn, Cu, B, Mo, Cl, and Ni) and macro-nutrients (N, Ca, K, Mg, P, and S). Many of Kervran's experiments are very convincing if we consider them without analysis at the micro-level.

On the other hand, Kervran's scientific views on these processes was very far from the modern understanding (and even the understanding of his time) of the general laws of nuclear processes and nuclear reactions. For example, it allowed the reversibility of the nuclear reaction: $K^{39} + p^1 \leftrightarrow Ca^{40}$ and the possibility of the decay reactions $Cl \rightarrow F + O$, $P \rightarrow Mg + Li$, $Ca \rightarrow Mg + O$, $Fe \rightarrow Mn + p$, which are incompatible with energy conservation laws. To produce such processes one would need a very large amount of energy $Q \approx$ 5–20 MeV, and there is not such large source in biological systems!

Another unreasonable hypothesis of Kervran was the prediction of the existence of special enzymes, which provide a direct space long distance transition of nucleons between different nuclei. On this basis, he believed that the transmutation of isotopes in biological systems is a special process, the mechanism of which is fundamentally different from analogous reactions in other, non-living physical systems. There is no justification in physics for such a statement!

Of course, in his arguments and comments, Kervran often spoke of the role of isotopes in nuclear transmutations. It is impossible to logically describe any nuclear reaction without considering specific isotopes. But he did not actually conduct a consistent isotopic analysis of his experiments. This is the basic error of Kervran's experiments

In our opinion, there is no reason to separate transmutation in biological systems from analogous nuclear transmutation in other physical systems. We believe that the undoubted specificity and rather high efficiency of such reactions at low energy are associated with two factors: (a) non-stationary topological features of growing biological systems at the micro-level; (b) the physiological characteristics of such objects (in particular, the need to rapidly integrate the synthesized element into the growing structure, which makes the process irreversible).

Specific biophysical aspects of the process of transmutation of isotopes in biological systems have been considered in detail in monographs [7,8]. We have conducted (and we are conducting now) research based on both these fundamental factors and on the basis of a combination of classical fundamental laws of nuclear physics with the most modern concepts of quantum mechanics. This concept – the possibility of the existence of coherent correlated states of interacting particles which can be formed and exist in dynamic systems – lends support to the possibility that nuclear processes can occur under conditions that are very different from the stringent conditions and requirements of the physics of classical nuclear fusion at high temperatures.

2. Experiments on Fusion and Transmutation of Stable Isotopes in Microbiological Systems

We began detailed studies of controlled nuclear processes in different microbiological systems in the early 1990s. The results of our research have been published in more than 20 articles (e.g. [11–26, 28–31]), three monographs [7,8,27] and two patents [9,10].

An analysis of possible ways transmutation might occur should be based on several fundamental logical premises:

- this process should be energy-efficient, i.e. transmutation should be characterized by a positive reaction energy $\Delta E \geq 0$;
- the transmutation reaction must in a certain sense be adapted to the biological system, the result of the reaction must be an isotope corresponding to one of the vital elements or its biochemical analogue;
- the initial isotope of the transmutation reaction should reflect (correlate) the quantitative composition of the medium;
- among the different initial isotopes that can participate in the reaction, preference should be given to the lightest isotopes for which the effect of potential barriers should be the smallest.

The main basis of our initial experiments was the principle of "*looking for what was lost under the street lamp*". This principle corresponds to the rule: if you have lost something in the dark, then you should look under the street lamp, because in other (dark) places you will not find anything! This principle gave priority to a reliable method of recording products of potential nuclear reactions, supplemented by the possibility of accumulating of these products. Based on our understanding of these processes, we investigated the reality of transmutation of stable isotopes based on the basic reaction $Mn^{55}+ d = Fe^{57}$ (see [9,12–19]).

The result of this reaction is the formation of a rare Mössbauer isotope Fe^{57} in a heavy water medium, where together with the microorganisms and macronutrients necessary for the growth of microbiological cultures, there was a manganese salt, but iron was absent. A very important advantage of this reaction is that the daughter isotope can be identified by both "standard" mass spectrometers (TIMS, SIMS, "time of flight", etc.) and selective Mössbauer mass spectrometers. In these initial experiments, there were no iron salts in the standard salt-feeding medium, but there was a manganese salt $MnSO_4$ (concentration about 0.01%). All components of the nutrient medium were dissolved either in heavy water (in the transmutation experiments) or in light water (in the control experiments). The total admixture of iron in the nutrient medium did not exceed 10^{-5}%.

We conducted our initial experiments on fusion of the rare stable Mossbauer Fe^{57} isotope in "pure" microbiological cultures of *E. coli* and *Saccharomyces cerevisiae T-8*. The typical duration of these experiments was 2–3 days, after which the growth of the cultures stopped due to a change in acidity and self-intoxication of cultures by metabolic products. This reaction was successfully produced and identified by Mössbauer and time-of-flight spectrometers. The experimental efficiency of this transmutation reaction was calculated to be:

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

This means that 10^{-8} Fe^{57} nuclei were synthesized per one Mn^{55} nucleus and per second. This was calculated by analysis of the Mössbauer resonance (see Fig. 1, top left, spectrum a).

The next series of experiments on transmutation was carried out on the basis of the reaction $Na^{23}+ P^{31} = Fe^{54}$ with the participation of medium-mass isotopes Na^{23} and P^{31}. Its expected product is another rare iron isotope Fe^{54}. This reaction was studied in light water and contained, in addition to the main typical chemical elements (including salt of Na), also the salt K_2HPO_4. In control experiments this salt was absent. Corresponding results of mass-spectrometric analysis of the grown culture are presented in Fig. 1 (three photos).

The efficiency of this reaction was approximately the same as at creation of Fe^{57} isotope. This is a very surprising result, since the height of the potential barrier for the last reaction is 6.5 times greater than the previous one!

These experiments were further optimized by using of MCT granules which contain the synthrophic association of many thousands of different types of microorganisms which can effectively grow for a long time in a very aggressive toxic environment (high acidity, high level of radiation, etc.). In Fig. 1 (top right) the Mössbauer spectrum of dried MCT granules after its growth during 30–50 days in a medium similar to the case discussed above of "pure" cultures for the realization of $Mn^{55}+ d = Fe^{57}$ reaction. The maximum transmutation efficiency was calculated to be:

$$\lambda = \Delta N(\mathrm{Fe}^{57})/N(\mathrm{Mn}^{55})\Delta t \approx 10^{-6}.$$

This means that 10^{-6} Fe^{57} nuclei was synthesized per one Mn^{55} nucleus and per second, that we have obtained in these experiments with synthrophic associations, exceeding the experimental results conducted with "pure" microbiological cultures by 80–100 times!

Subsequent experiments were aimed at studying the possibility of transmutations not only of light and medium-weight isotopes, but also of heavy nuclei. The reaction of a transmutation of a stable cesium isotope into the barium isotope $Cs^{133}+ p = Ba^{134}$ was chosen as the object of research [32]. The expediency of such studies was due to the possibility of transmutation and deactivation of the Cs^{137} radioactive isotope. These experiments were carried out with

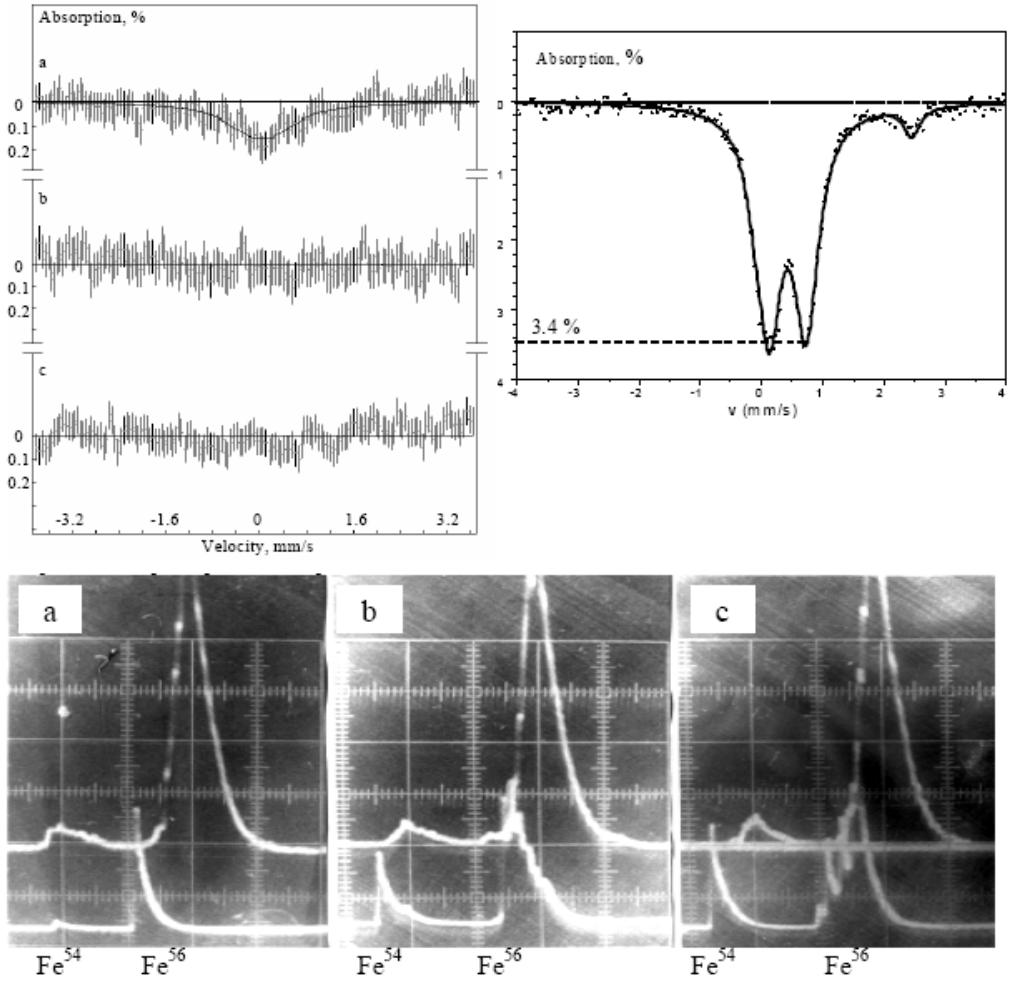


Figure 1. The top left is the Mössbauer spectrum of the dried microbiological culture of *Saccharomyces cerevisiae T-8*, grown in a liquid nutrient medium based on: (a) heavy water D_2O in the presence of the Mn^{55} isotope; (b) light water H_2O in the presence of Mn^{55}; (c) heavy water D_2O in the absence of the Mn^{55} isotope. At the top right – Mössbauer spectrum of MCT granules grown in a nutrient medium based on heavy water D_2O in the presence of the Mn^{55} isotope and the absence of iron (or its minimum amount as an impurity). Below – a fragment of the mass spectrum of the same culture, grown in a nutrient medium based on H_2O in the presence of Na^{23} and P^{31} (b), (c) and the absence of P^{31} (a). The upper graphs on each of the photos below correspond to the control spectrum of the natural iron masses obtained in the same series as the corresponding lower graphs.

much more effective types of synthrophic associations "Biocatalyst" (both aerobic and anaerobic) including a special kind of methanogenic bacteria of Sea Sludge. The scheme of the experiments is shown in Fig. 2.

The light-water nutrient medium contained glucose, dissolved base salts of the main macro-nutrients and micro-

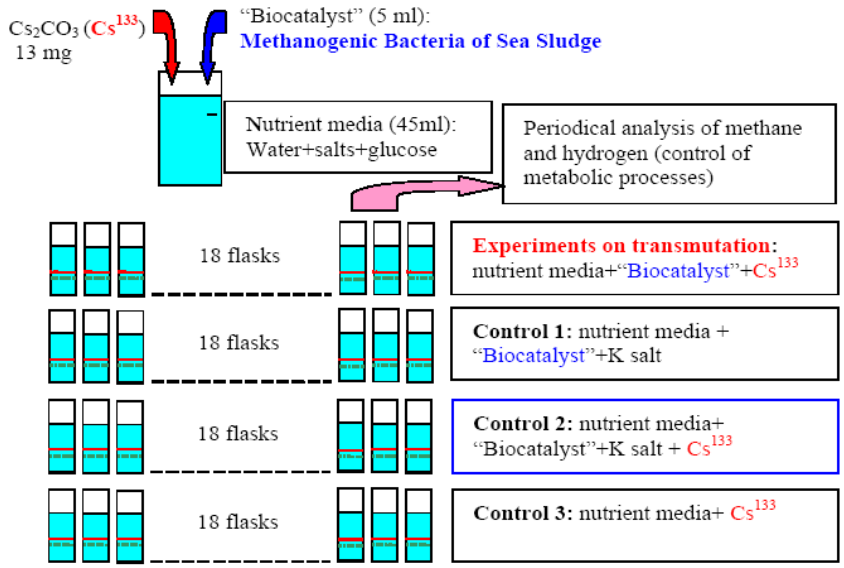


Figure 2. The scheme of experiments on transmutation of heavy stable isotopes by anaerobic cultures.

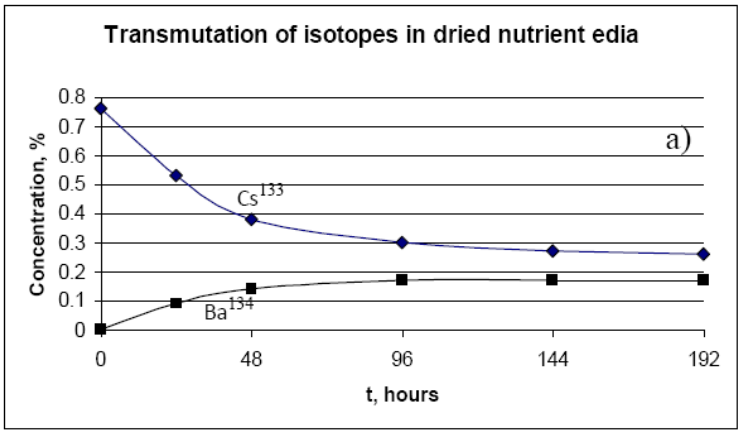
nutrients (including NH_4NO_3, $CaSO_4$, and $MgSO_4$), as well as stable cesium as the Cs_2CO_3 salt. But it did not contain potassium, which is vital for the growth of the organisms included in these associations. Barium is a biochemical analogue of potassium and in the absence of potassium, barium can be used for the growth of microbiological cultures.

During the growth process, samples were periodically taken from the experimental cuvettes, which were used to study the dynamics of the transmutation process. The results of these studies are presented in Fig. 3.

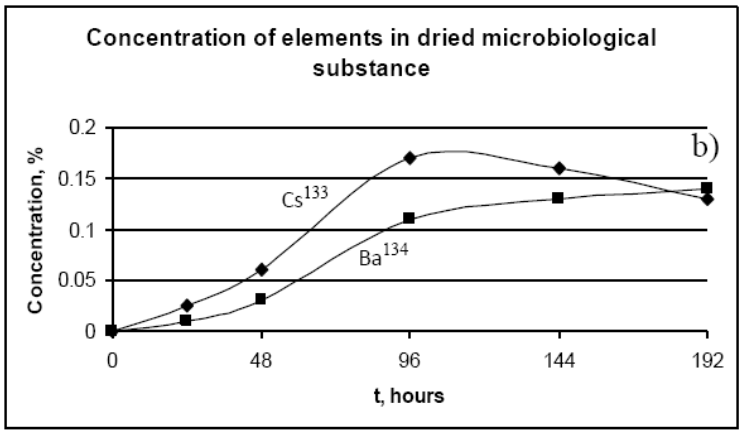
From these data it can be seen that in the process of growth of microbiological systems, there was continuous transmutation of cesium to barium, as well as partial absorption of cesium by growing microcultures (followed by a delayed transmutation into barium). This is especially evident in Fig. 3a, in which synchronized transmutation of Cs^{133} and Ba^{134} takes place in a liquid nutrient medium. From the data presented in Fig. 3b it can be seen that in the volume of the biological substance, active absorption of Cs^{133} initially takes place, and is then followed by the delayed transmutation of it into Ba^{134}. The initial ($t = 0$, $\rho_{Cs^{133}} \approx 13$ mg/cell) and final ($t = 192$ h, $\rho_{Cs^{133}} \approx 6.5$ mg/cell) concentrations of Cs^{133} isotope in the dried nutrient medium and in the biological substance corresponds to the efficiency of the transmutation reaction of concentration versus time in the liquid sample. In this experiment on transmutation, Ba^{134} atoms are synthesized at the rate of $\lambda = N(\mathrm{Ba})/N(\mathrm{Cs}^{133})\Delta t \approx 10^{-6}$ s^{-1} per atom of Cs^{133} nucleus and per second. In control experiments that were conducted without the addition of microcultures the concentration of Cs^{133} was not changed during experiments.

3. Experiments on Transmutation of Radioactive Isotopes in Microbiological Systems

Successful experiments on the transmutation of stable isotopes, which we have carried out since 1994, have made it possible to proceed to the solution of the problem of radioactive isotope transmutation in microbiological systems. To solve this problem, the optimum synthrophic microbiological associations we use are the ideal "tools", since they can



(a)



(b)

Figure 3. (a) Decrease of Cs^{133} and increase of Ba^{134} isotopes concentration versus time after evaporation of concentrated liquid samples of nutrient media taken from the bottom part of the bottle (plastic bioreactors); (b) change of Cs^{133} and Ba^{134} isotope concentrations versus time in dried microbiological substance. Initially, the biological substance contained no cesium or barium.

successfully grow and develop in very strong radiation fields.

3.1. Experiments on utilization of the reactor isotope Ba^{140}

The first series of experiments was devoted to the possibility of influencing the activity of reactor water samples extracted from the primary coolant loop of the light-water nuclear reactor of the Kiev Institute for Nuclear Research.

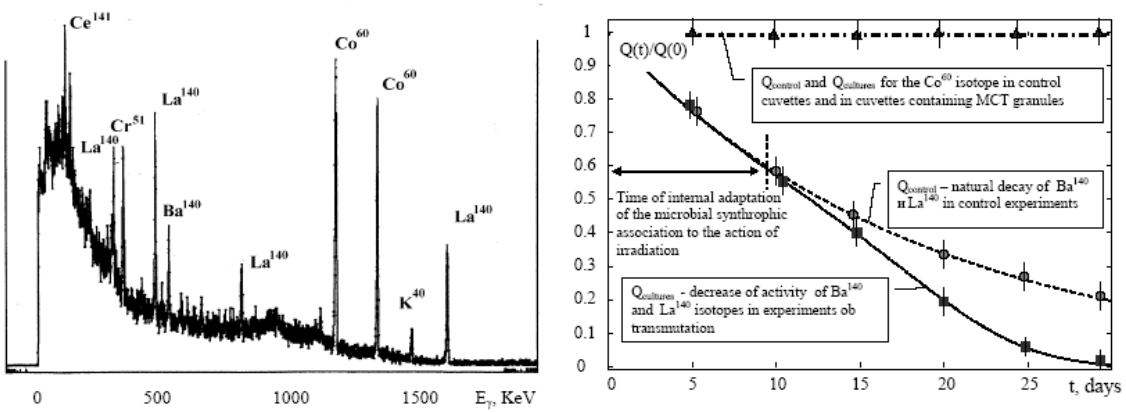


Figure 4. *Left*: spectrum of gamma-radiation of distilled water from the primary system of the light-water nuclear reactor. The data correspond to the 10th day after extracting a sample of the active water from the reactor. *Right*: the dependence of activity $Q(t)$ of Ba^{140}, La^{140} and Co^{60} reactor isotopes in reactor water samples in the transmutation experiment (here $Q_{\rm cultures}$ is the activity of cuvettes at the presence of metabolically active microorganisms) and in control cuvettes without microorganisms ($Q_{\rm control}$).

This water had an activity of about 10^{-4} Curie/l and contained a number of highly active unstable isotopes (in particular, Na^{24}, K^{40}, Co^{60}, Sr^{91}, I^{131}, Xe^{135}, Ba^{140}, La^{140}, Ce^{141}, and Np^{239}). The gamma- spectrum of this water is shown in Fig. 4 (left).

Water samples of the same volume (about 5 ml) were placed in similar glass thin-walled closed cuvettes with a volume of about 10 ml. The same mass of MCT granules was placed in the cuvette with active water. The remaining cuvettes with water (but without granules) were controls. The essence of the research consisted of a periodic study (over 5 days) of the gamma spectrum of the active water. To eliminate the influence of the distance factor (which may be associated with a small increase in the volume of a mixture of water and granules with the growth of microbiological cultures or their spatial redistribution), we used an amplitude gamma-detector with a large germanium crystal, in which the cells under study were placed in the center.

Figure 4 (*right*) shows the averaged results of the dependence of the activity of the isotopes La^{140} and Co^{60} in cuvettes with MCT granules ($Q_{\rm cultures}$) and in control cells ($Q_{\rm control}$) from the time after the beginning of the experiments.

From these data, it follows that the activity of the long-lived Co^{60} isotope remains constant throughout the measurement period (both in the control cuvettes and in the cuvettes with MCT granules). This indicates that systematic methodological errors (such as a change in the volume of the liquid, a change in the position of the cell relative to the center of the crystal of the detector, etc.) did not have a significant effect on the result. At the same time, a fundamentally different law for the reduction of the activity of the isotope La^{140} in both types of the cuvettes was discovered. This isotope has a relatively short lifetime ($\tau_{\rm La} = 40.3$ h) and is a daughter unstable isotope of the longer-lived Ba^{140} isotope, whose lifetime is $\tau_{\rm Ba} = 12.7$ days.

The initial activities of the Ba^{140} and La^{140} isotopes, on the 10th day after the extraction of the water from the reactor core for each of the cuvettes was, respectively,

$$Q_{\rm Ba-140} = 1.46 \times 10^{-7} \text{ Curie/l} \quad \text{and} \quad Q_{\rm La-140} = 2.31 \times 10^{-7} \text{ Curie/l}.$$

Since $\tau_{\rm La} \ll \tau_{\rm Ba}$, the observed decrease in La^{140} activity reflected a decrease in the activity of Ba^{140}. These results

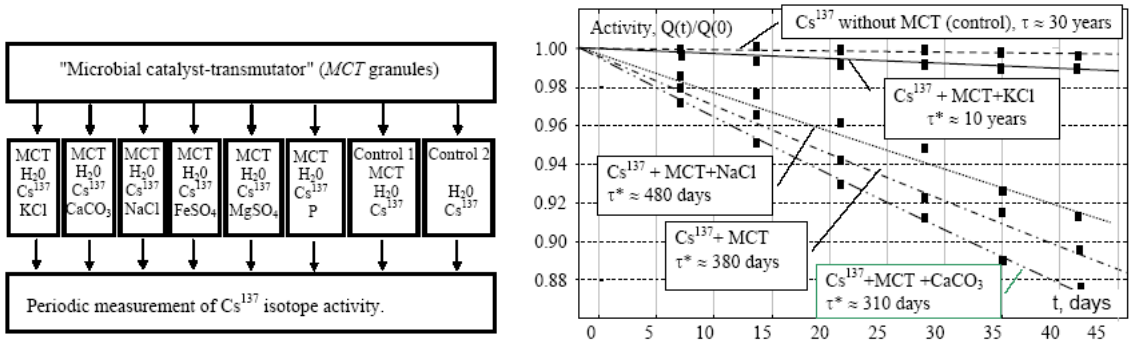


Figure 5. Scheme of studies of the utilization of Cs^{137} isotopes under different conditions and the results of experiments on the accelerated utilization (deactivation) of the Cs^{137} isotope in "biological cells" in the presence of MCT and various chemical elements.

indicate that in this experiment there is a transmutation of the radioactive Ba^{140} isotope into a non-radioactive isotope of another element. The analysis showed that the most probable reaction of such a transmutation is the following:

$$Ba^{140} + C^{12} = Sm^{152}.$$

This reaction is energy-efficient and is characterized by a positive reaction energy

$$\Delta E = E(A_{\rm Ba}Z_{\rm Ba}) + E(A_{\rm C}, Z_{\rm C}) - E(A_{\rm m}, Z_{\rm m}) = 8.5\ \text{MeV}.$$

The carbon required for this reaction is abundant in the MCT granules.

3.2. Experiments on utilization by accelerated transmutation of long-lived reactor Cs^{137} isotope in growing microbiological radioactive waste structures

Very promising results in the transmutation of reactor Ba^{140} and La^{140} isotopes with an average lifetime stimulated experiments on transmutation (and utilization) of the most biologically dangerous long-lived radioactive Cs^{137} isotope. During the last 15 years we conducted several successively optimizing studies aimed at finding the most optimal method for such utilization.

Our initial experiments were conducted with the participation of our colleagues V.N. Pavlovich and A. Odintsov from the Institute for Nuclear Research and the Institute for Nuclear Safety Problems in Kiev [20]. The microbiological granules of MCT were prepared by our colleague A.B. Tashirev from the Institute of Microbiology in Kiev.

In these experiments we used the same closed glass cuvettes, each containing 10 ml of distilled water, in which the salt containing Cs^{137} was dissolved. The total activity of each of the cuvettes was about 2×10^4 bq. The scheme of investigations is shown in Fig. 5.

The same mass of MCT granules was placed in seven cuvettes. In six cuvettes, purified salts of K, Ca, Na, Fe, Mg, and P were added to the active water. These chemical elements are among the most vital for any living system. The main purpose of using such additives was to find ways to block possible channels of transmutation, because if a specific chemical element is present in the system , and it is one of the vital elements needed to sustain life, then the assimilation of its biochemical analogue during transmutation becomes unlikely. In addition, such substitutions were carried out with the goal of creating the optimal composition of micro-nutrients for rapid growth of microorganisms. The results

obtained below confirm the importance of such substitutions. Two additional cuvettes were used for monitoring: one contained the same radioactive water and MCT (but did not contain additional salts), and the other contained only radioactive water.

All of the cuvettes were closed and kept at a temperature of 20°C. The amplitude of the gamma-ray spectrum of the cuvette was measured every 7 days with the same detector, in which a Ge crystal was used. Particular attention was paid to reducing the influence of errors associated with the measurement process. For this purpose, we used cuvettes with a low height, and the detector with a large Ge crystal. The cuvettes were set at the same position in the center of the crystal of the detector for each measurement.

The results of the changes in the relative activity of the Cs^{137} isotope are shown in Fig. 5 (*right*). The fastest decrease in activity was observed in a cuvette containing a calcium salt. This was equivalent to a decrease in the lifetime of Cs^{137} by a factor of 35 to $\tau^* \approx 310$ days. This decrease in activity was not related to the accelerated decay, but was the result of reaction of the transmutation of the radioactive Cs^{137} isotope to the stable Ba^{138} during the reaction:

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

with the participation of water protons. The reaction energy is positive and equal to $\Delta E = 5.58$ MeV.

Concerning the "biological expediency" of such a hypothesis, it should be noted that Ba^{2+} and K^+ ions are biochemical analogs: they have approximately the same ionic radii in the divalent state ($R_{Ba} \approx 1.4$ Å, $R_K \approx 1.33$ Å). Since the replaceable element (potassium) is one of the vitally important trace elements, the probability of such a substitution is quite large and the ions of the synthesized barium can replace potassium ions in metabolic processes with the growth of cultures. Such a substitution appears to be more effective than the "direct" replacement of potassium by cesium in the case of potassium deficiency. This can be seen from the large difference in the ionic radii of cesium $R_{Cs} \approx 1.65$ –1.69 Å and potassium $R_K \approx 1.33$ Å.

Another interesting question relates to the cause of the increased efficiency of utilization when using an additional calcium salt. Apparently, this effect is associated with the general pattern of the metabolism of microbiological cultures: the optimal growth of culture corresponds to the necessary balance of all micro-nutrients and macro-nutrients. It is possible that it was a calcium deficiency that was the "bottleneck" that inhibited the growth process and accompanying transmutation in a particular growing microbiological system.

In recent years, further improvements in bio- and nuclear technology has led to significant progress in understanding these transmutation processes, using more optimal biological substances and more optimal controlled modes of their growth. These new types of syntrophic associations were initially tested at the transmutation of stable isotopes as described above. These successes and a deeper understanding of the physical and biological processes accompanying nuclear phenomena in dynamic systems have led to significant progress and optimizing the process of transmutation. This is clearly demonstrated by the high transmutation efficiency of the stable Cs^{133} isotope considered above.

The last experimental results are the following. The mean decrease in Cs^{137} concentration over 14 days was 23%, based on parallel experiments, which corresponds to an acceleration of deactivation more than 200 times in relation to the spontaneous decay and acceleration of the transmutation process by six times in relation to the action of the MCT syntrophic association.

In some cases, a decrease in the concentration of Cs^{137} in these experiments reached 70% in 14 days (Fig. 6) [32]. To suppress measurement errors associated with the possible redistribution of radioactive waste to the volume of experimental samples, high-sensitivity detectors located at a great distance from the investigated samples were used. These experiments were conducted with participation of our colleagues S. Gaidamaka and V. Kashcheev.

We also developed a technology for even deeper deactivation (up to 100%) of the radioactive medium in 30–50 days. Such a significant increase in transmutation efficiency makes it realistic to use liquid radioactive waste in the near future.

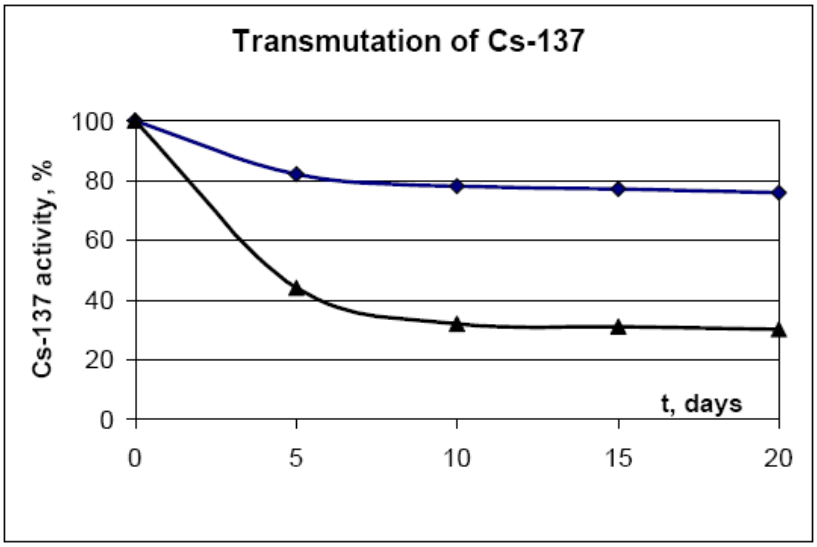


Figure 6. Reduction of gamma-activity of Cs^{137} aqueous solution in the optimized syntrophic association. The upper graph is the average data for the series of experiments, the lower is the similar reduction at the most optimal conditions from the same series.

4. Physical Foundation of Biological Transmutation

To explain the physical basis of such a transmutation, it is necessary to take into account three important circumstances inherent in any reaction involving charged particles with low energy: anomalously high probability of a tunneling effect at low particle energies; complete absence of radioactive daughter isotopes; and extremely strong suppression of concomitant gamma radiation. After a detailed analysis of all the experiments (both on biological transmutation and related to low-temperature nuclear reactions in "ordinary" physical systems) we came to the following conclusion: the most effective method for producing transmutations and for a very significant increase in the transparency of a potential barrier at low particle energies is associated with the use of coherent correlated states (CCS) of particles interacting with the atoms (nuclei) forming this barrier [33–49]. The most characteristic property of CCS is the possibility of forming controlled giant energy fluctuations of a particle whose amplitude can be thousands or even millions of times greater than the average (thermal) energy of a particle and reach values $\delta E \approx$10–50 keV and more. In a concentrated form, this is reflected in the modified uncertainty relations, called the Schrödinger–Robertson uncertainty relations:

$$\delta p\,\delta q \geq G_{\rm pq}\hbar/2, \quad G_{\rm pq} \equiv 1/\sqrt{1-r_{\rm pq}^2}; \quad \delta E \delta t \geq G_{\rm Et}\hbar/2, \quad G_{\rm Et} \equiv 1/\sqrt{1-r_{\rm Et}^2},$$

in which the product of the fluctuations of the corresponding dynamic variables (coordinate, momentum, energy, time, etc.) is determined by the corresponding correlation coefficients $r_{\rm pq}$ and $r_{\rm Et}$ (and coefficients of correlation efficiency $G_{\rm pq}$ and $G_{\rm Et}$, the magnitudes of which are limited by the intervals $0 \leq |r_{\rm pq}|, |r_{\rm Et}| \leq 1,\ 1 \leq G_{\rm pq}, G_{\rm Et} < \infty$ [34–49].

Direct calculations have shown that in a stationary state in any system $r_{\rm pq}^2, r_{\rm Et}^2 \ll 1$ and $G_{\rm pq}$,$G_{\rm Et} \approx 1$. In this result, Schrödinger–Robertson uncertainty relations take the form of well-known Heisenberg uncertainty relations. Another situation takes place in dynamic systems, including living objects. It is well known that the growth front of

any biological object is never ideally homogeneous – local heterogeneities (potential nano-wells with size $L \approx 2...4\,\text{Å}$) are always formed, which are leveled and eliminated during the growth process. Each of these nano-wells is a non-stationary oscillator for particles that are localized in it. In the process of the dynamically changing of the parameters of these wells, CCS can be formed for these particles with a large value of the coefficients of correlation efficiency (up to $G_{\text{pq}}, G_{\text{Et}} \geq 10^3 - 10^4$ and more [35–49]) and, accordingly, with unlimitedly increasing fluctuations of kinetic energy:

$$\delta T = (\delta p)^2/2M \geq G_{pq}^2 \hbar^2/8M(\delta q)^2 \approx 5 - 100\ \text{keV},$$

which can exist for a relatively long time, $\delta t \geq G_{\text{Et}}\hbar/2\delta E \approx 10^{-17} - 10^{-18}$ s and which is enough both to pass through the potential barrier and stimulation of nuclear reaction.

In [33–49] different modes of CCS formation under different methods of weak external action on particles are discussed and investigated – squeezing or expanding potential well [33,34,38,41], periodic action of resonant [38,41] and non-resonant [44,45] frequencies, pulse modulation of potential well [45,47] and action of a pulsed magnetic field [47], CCS formation under influence of random defusing fluctuations [42] and many other factors.

An exact calculation, carried out using quantum mechanics, shows that during the formation of the CCS there is a very significant increase in the transparency coefficient of the potential barrier from that which is typical of slow particles (at room temperature) and "usual" uncorrelated states very small values $D \approx 10^{-100} - 10^{-500}$, up to large values $D \approx 10^{-1} - 10^{-5}$ for correlated states. These are in good agreement with experiments. From this point of view, the growth of the non-stationary zone of any biological object represents a system of potential disposable nanoreactors, in which a reaction involving these particles is possible. Similar processes can occur in the space between two cells during cell division, in mitochondria, at the entrance to biological membranes, etc.

5. Conclusion

The experimental results presented here, and a very short theoretical analysis substantiating these data, show that the method of transmutation of stable and radioactive isotopes in the presence of growing microbiological cultures and their associations may be an effective way of solving many fundamental problems of ecology and industry. This method can be used to deactivate a large amount of radioactive liquid [10], to produce rare isotopes [9], to dispose of chemical toxic materials, and so on. The process of nuclear transmutation is associated with controlled nuclear processes at low energy due to the use of coherent correlated states, which contributes to a very sharp increase in the transparency of the potential barrier. At the molecular level, the specificity of the interaction and motion of the microparticles is fully described by the laws of quantum mechanics and electrodynamics for both living and non-living objects. From this point of view, there is no difference between them! We have also shown [47–49] that reactions stimulated by the formation of coherent correlated states (and formation of very large fluctuations of momentum and kinetic energy) never lead to the formation of radioactive daughter nuclei, and are characterized by the strong suppression of gamma-radiation. Such processes can be successfully implemented on any system, if the necessary prerequisites are met. They should not be called by the semi-mystical term "biological transmutation". These are usual nuclear reactions, but they are produced in growing biological systems and under the catalytic effect of dynamic electric fields accompanying atomic-molecular processes that take place with growth in these systems. Such a process can be called "nonstationary dimensional nuclear catalysis" and it can occur both in living and in nonliving physical systems.

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