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Experiments and Methods in Cold Fusion

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Preface

For more than a century, questions have been raised about a mismatch in the mass balance that occurs during the growth of plants and animals. However, this mismatch has not received the attention of mainstream academia. The explanation for this question was released when Kervran published a book, "Biological Transmutation" in 1962. In addition, Komaki revealed in the late 1960s that such biological transmutation also occurs in microorganisms.

It is sometimes said that microbes own the earth. The number of microbes in a human body greatly exceeds the number of cells. Some people wonder whether the human body might be considered just a host for microorganisms. In fact, it was microorganisms that allowed life to flourish on this planet. Microorganisms make up the largest proportion of the total weight of organisms on earth.

Human civilization is utterly dependent on energy. The core of the first Industrial Revolution was that mankind secured a power source by inventing steam engines. Today, boiling water technology is advanced, and efficiency is improved, but the basic principle is still the same. Nuclear power used as a heat source for boiling water is considered an ideal energy source in that it does not emit carbon dioxide, which is the main cause of climate change. However, the biggest problem is that radioactive waste is harmful to living organisms. This problem has already been starkly revealed by the Chernobyl and Fukushima nuclear power plant accidents.

When the atomic bombs were dropped on Hiroshima and Nagasaki, scientists who participated in atomic bomb development expected that people would not be able to live in these two cities for the next 100 years. This is what they extrapolated from the results of the Nevada desert atomic bomb test sites. But in just over a year, both cities reverted into an environment where people can live. What happened? The difference lies in the fact that there are almost no microorganisms in the Nevada desert while the two cities had lots of soil microorganisms. Presumably, it was the microorganisms that remediated the environment so quickly. Indeed, microorganisms are very powerful protagonists of the earth. Microorganisms are the strongest living organisms tested to survive intense radioactive radiation so far.

Since 1989, when cold fusion was reported, the results of research in this field can be summarized in two major facts. One is that the output heat energy is larger than the input electrical energy and the other one is that low energy nuclear transmutation is observed. These results appear to violate common sense knowledge that elemental conversion is possible only with high energy accompanied by massive energy generation. Biological transmutation has begun to attract attention again after low energy nuclear transmutation was reported.

Although the mechanism has yet to be clarified, it may be explained from the perspective of oriental philosophy. The world is composed of yin and yang, and the world moves through the harmonious interaction between yin and yang. When the same properties meet each other, such as yin and yin, or yang and yang, they collide with each other and the energy is negative and destructive. However, if yin and yang meet together, they are in harmony and the energy is soft and creative. In other words, fission is a physical inorganic reaction and fusion is a biological organic reaction. Nuclear fission can be likened to collisions between the same poles, i.e., yin and yin or yang and yang, while nuclear fusion can be likened to the harmony of yin and yang. In this sense, nuclear fusion in a living body may be possible with far less energy compared to nuclear fission. This may give us a hint how biological transmutation is possible with such low energy.

If harmful radioactive elements can be converted into a safe, natural elements by biological transmutation using microorganisms, a permanent solution for treating radioactive waste or contaminated soil can be obtained. Fortunately, experiments have shown that this is possible. This means that active reduction of the intensity of radioactivity may be plausible, rather than just waiting for the intensity of radiation to diminish naturally.

These are the proceedings of the International Conference on the Application of Microorganisms for the Radioactive Waste Treatment held in Busan, South Korea, in May 2018. I hope that the papers published here in the future will be a catalyst for mankind to escape the fear of radioactive waste. Microorganisms are the masters of the earth and have the power to solve any disruption. It just takes time.

Sincerely,

Dr. Sanghi Rhee
(*Organizer and Chairperson*)
January 2019

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Research Article

An Experiment in Reducing the Radioactivity of Radionuclide (^{137}Cs) with Multi-component Microorganisms of 10 Strains

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Abstract

In order to observe the effect of multi-component microorganisms on the radiation intensity of a radioactive ^{137}Cs solution, a multi-component microorganism composed with 10 strains was designed and utilized in the experiment. It was composed of the radioactivity resistant *Bacillus spp*., aerobic bacteria which have a high temperature resistant and good biodegrade ability, anaerobic lactic acid bacteria, highly resistant to toxicity and good polymer degradable yeast, and photosynthetic strains with a better utilization of proton and high production rate of H^+. An amount of 120 ml of this multi-component microorganism was mixed with 380 ml of deionized water. An amount of 0.159 ml of hydrochloric acid solution (0.1 mol/l) containing ^{137}Cs was added to this mixture to adjust the final radioactivity to be 50 kBq. The mixed 500 ml samples were irradiated at 12-hour intervals with light and shaken at about 120 rpm at 25°C in a shaking incubator. (continued on p. 2)
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Keywords: Biological transmutation, ^{137}Cs, Gamma-ray count rate, Multi-component microorganisms, Radioactivity

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(continued from p. 1) The radioactivity of the mixed solution was measured by a counter equipped with a high-purity Ge detector every other or 3 days. It was observed that the radiation intensity increased slightly at the beginning and then decreased to the 80% level compared to the control.

1. Introduction

In 1989, Martin Fleischmann and Stanley Pons reported that an electrolytic cell produced anomalous heat of a magnitude that could not be due to anything but nuclear processes [1]. Since then, many researchers have tried to reproduce their results and debated on its mechanism for almost 30 years. The mechanism is still not yet clear, however, the phenomenon is characterized by two facts; i.e., excess heat generation and nuclear transmutation. It has been renamed lattice assisted nuclear reaction (LANR), low-energy nuclear reactions (LENR) or condensed matter nuclear science (CMNS). Nuclear transmutation was confirmed through the comparison of the surface composition of the palladium electrode before and after the experiment. From these results, it can be understood that a nuclear reaction at low energy level is possible; reactions are not limited to the typical high energy nuclear reaction.

This phenomenon, LENR, provided a motivation to look at biological transmutations from different aspects which has been totally ignored by the scientific community [2]. Actually, it has been reported by a few pioneers from the early 19th century that biological transmutation occurs in a living body [3]. Among them, Kervran carried out a systematic approach to this phenomenon and reported it in his book, "Biological Transmutation" [4].

His experimental results were critiqued because of imperfect mass control, and Komaki carried out experiments using microorganisms to confirm the phenomenon of biological transmutation [5]. Microorganisms are much smaller than large sized fauna and flora and the change in mass balance and analysis can be monitored under strict conditions. Komaki studied eight kinds of microorganisms, including *Aspergillus niger* (IFO No. 4066), *Penicillum chrysogenum* (IFO No. 4689), *Rhizopus nigricans* (IFO No. 5781), *Mucor rouxii* (IFO No. 5773), *Saccharomyces cerevisiae* (IFO No. 0308), *Torulopsis wills* (IFO No. 0396), *Saccharomyces ellipsoideus* (IFO No. 0213), and *Hansenula anomala* (IFO No. 0118). He used specially designed culturing media such as Fe, K, Mg, and Ca deficients media to observe any change in the composition of media after the culturing and the behavior of the microorganisms with the insufficient supply of specific mineral elements. It was confirmed that biological transmutation occurred in a way that the microorganisms produced the necessary elements through transmutation. These results strongly support the previous observations of Kervran on biological transmutation, and it seems that it is a more general phenomenon which may occur in almost all living organisms including microorganisms.

Recently, Vysotskii and Kornilova showed more evidence for biological transmutation using modern spectroscopic techniques [6]. In particular, they used Mössbauer spectroscopy, which distinguishes isotopes of elements with good sensitivity. The experiments were performed with bacteria, including; *Bacillus subtilis, Escherichia coli*, *Deinococcus radiodurans*, as well as a yeast culture *Saccharomyces cerevisiae*.

When manganese was introduced by adding an $MnSO_4$ solution, a clear peak of ^{57}Fe was measured, indicating that manganese had been transmuted into iron. In natural iron,^{57}Fe represents only 2.1% of the total iron content and there is no possible interference with any other element. In another analysis by time-of-flight mass spectroscopy, the mass 57 peak was as large as that of mass 56, the most abundant iron isotope. This is another confirmation of the production of ^{57}Fe.

When the bacteria were cultured in a medium without iron, they produced an ^{54}Fe peak as large as ^{56}Fe after the bacteria grew. In natural iron,^{54}Fe represents only 5.8% of the total iron content. Vysotskii and Kornilova proposed the following reaction to explain the formation of ^{54}Fe:

$$^{23}\mathrm{Na} + {}^{31}\mathrm{P} \rightarrow {}^{54}\mathrm{Fe}.$$

After confirming the biological transmutation, they felt to carry out an experiment to observe the transmutation of radioactive elements. In principle, if biological transmutation is possible, there is no reason to think it will not work

for radioactive elements, except that the microorganisms may be killed due to the exposure of strong radiation such as gamma rays. And, in fact, Vysotskii and Kornilova have successfully observed the biological transmutation of ^{137}Cs radioactive element.

$$^{133}\mathrm{Cs} + {}^{1}\mathrm{H} \rightarrow {}^{134}\mathrm{Ba}.$$

Additionally, they also observed that the rate of biological transmutation was increased up to 20 times depending on the inorganic salts added to the culturing media. However, it was observed that using a single species of microorganisms is not so effective in increasing the efficiency of biological transmutation because the microorganisms could not sustain life for long time. To overcome this difficulty, they adopted multi-component microorganisms composed of hundreds of different species in a symbiotic state. The multi-component microorganisms showed much stronger resistance to the exposure of radiation due to their strong ecosystem. They could extend the life of the microorganisms three times longer compared to the single species of microorganisms. It was found that ^{137}Cs, which has a radioactive half-life of 30 years, transmutes within 310 days into stable ^{138}Ba. They proposed the nuclear reaction as:

$$^{137}\mathrm{Cs} + {}^{1}\mathrm{H} \rightarrow {}^{138}\mathrm{Ba}.$$

These are the best experimental proofs of biological transmutation heretofore, and they show the promising application of microorganisms for the treatment of radioactive nuclear waste. However, the details of the composition of multi-component microorganism are not known yet, and this hinders the reproduction of the experiments. In addition to this, it is difficult to study the mechanism of biological transmutation without knowing the composition of microorganisms.

To resolve this problem, we designed a multi-component microorganism with a small number of different species. By this approach, the study on the mechanism of biological transmutation can be easier. The multi-component microorganisms were prepared by the Coenbio Research Institute, which has been developing bioremediation technologies for treating soil and groundwater contaminated with toxic heavy metals for over 10 years. The microbial products developed by the institute have been applied to large-scale contaminated soil such as at abandoned mines and contaminated river sedimentation sludge. We have obtained a promising result in preliminary experiments showing that multi-component microorganisms with less than 10 microorganism species can be utilized for the treatment of nuclear waste treatment.

2. Materials and Methods

In order to study the change of ^{137}Cs radiation intensity by microorganisms, 10 specific strains of microorganisms were selected and the mixed microorganism system was designed. It was composed of the radiation resistant *Bacillus* spp., aerobic bacteria which have a high temperature resistance and good biodegrade-ability, yeast which is highly resistant to toxicity and has a good polymer decomposition capability, and photosynthetic strains with a good utilization of proton and high production rate of electron and H^+. These microorganisms were dissolved in a solution.

A solution contain ^{137}Cs was dissolved in hydrochloric acid (0.1 mol/l) to make its radioactivity to be about 100 Bq/g. The experimental samples of 500 ml were prepared by mixing 120 ml of the solution of microorganisms and 380 ml of deionized water. To this mixture, 159 μl of hydrochloric acid containing ^{137}Cs was added to make the total radioactivity of the sample 50 kBq. This sample was poured into a 1-liter capacity Erlenmeyer flask (Fig. 1). The prepared samples were irradiated at 12-hour intervals with room light and shaken at about 120 rpm at 25°C in a shaking incubator. The gamma rays from the mixed solution was measured every other or 3 days with a counter equipped with a high purity p-type Ge detector having relative detection efficiency of 70%. Figure 2 shows the arrangement of the flask in a custom designed holder above the detector.

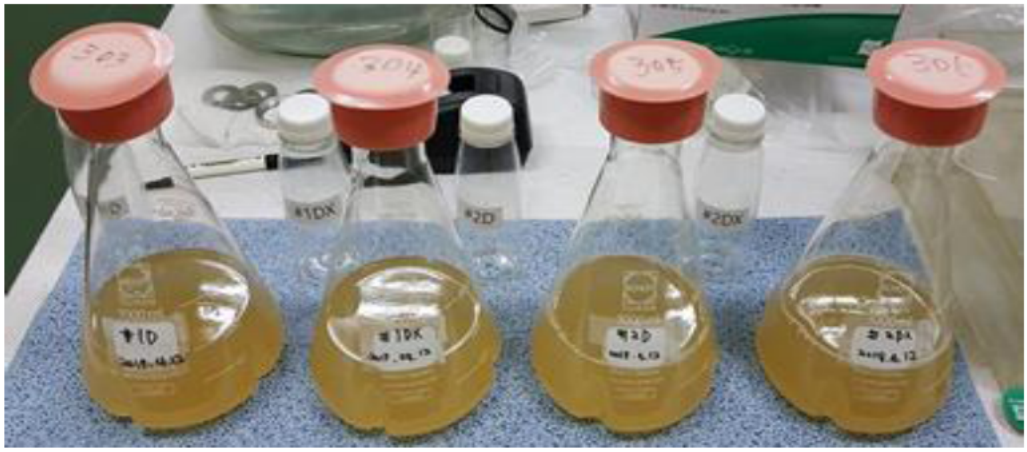

Figure 1. The prepared samples (500 ml) with mixed microorganisms and 50 kBq of ^{137}Cs.

3. Results and Discussion

Figure 3 shows the result of count rate measurements. It is clearly demonstrated that the gamma-ray intensity from ^{137}Cs has been decreased to the level of less than 90% compared to the initial level. Interestingly, the count rate increased by 8% at the beginning and then it began decreasing. This is the same tendency which was observed by Vysotskii and Kornilova [6]. The control sample did not show any change in the level of the activity until the experiment was finished.

The unique pattern of count rate variation, increase and then decrease, implies that there would be two different mechanisms in biological transmutation. They may be related to the acceleration of ^{137}Cs decay and transmutation, respectively. The analysis on the composition of the sample is undergoing and we focused on the observation of ^{138}Ba,

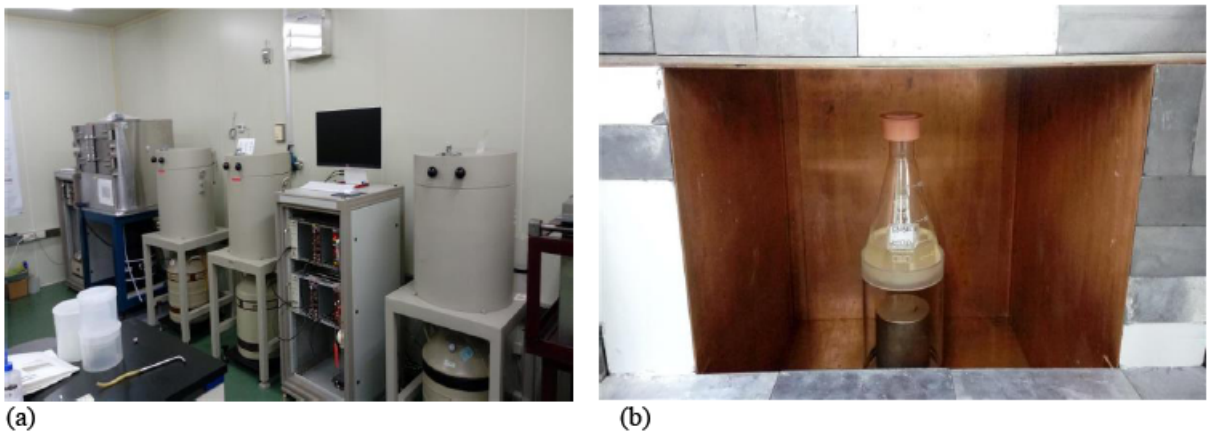

Figure 2. The experimental setup equipped with high-purity Ge detector (a), and the sample flask above the detector (b).

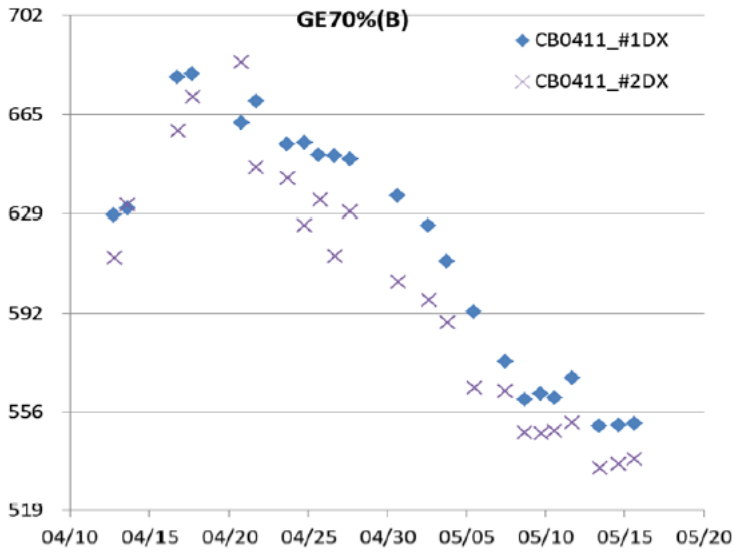

Figure 3. The change of γ-ray counting rate (s^{-1}) from ^{137}Cs over time (month/day).

which can be a solid evidence of biological transmutation of ^{137}Cs as explained above.

This result shows that multi-component microorganisms can be utilized for the remediation of soil and groundwater contaminated with radioactive materials, and to restore the contaminated ecosystem. Further experiments will be carried out to explore the mechanism of biotransmutation.

4. Conclusion

It has been shown that a multi-component microorganism with a smaller number of species, less than 10 kinds of species, can be effectively utilized for the decrease of radioactivity of ^{137}Cs. This phenomenon is an additional evidence of biological transmutation and it seems that there are two stages of reaction in biological transmutation. Acceleration of decay occurs first and is then followed by an overall decrease in the counting rate.

Acknowledgment

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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.
 ISSN 2227-3123

Keywords: Coherent correlated states, Deactivation of radioactive waste, Isotope transmutation, Low energy nuclear reactions, Synthrophic microbiological associations

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

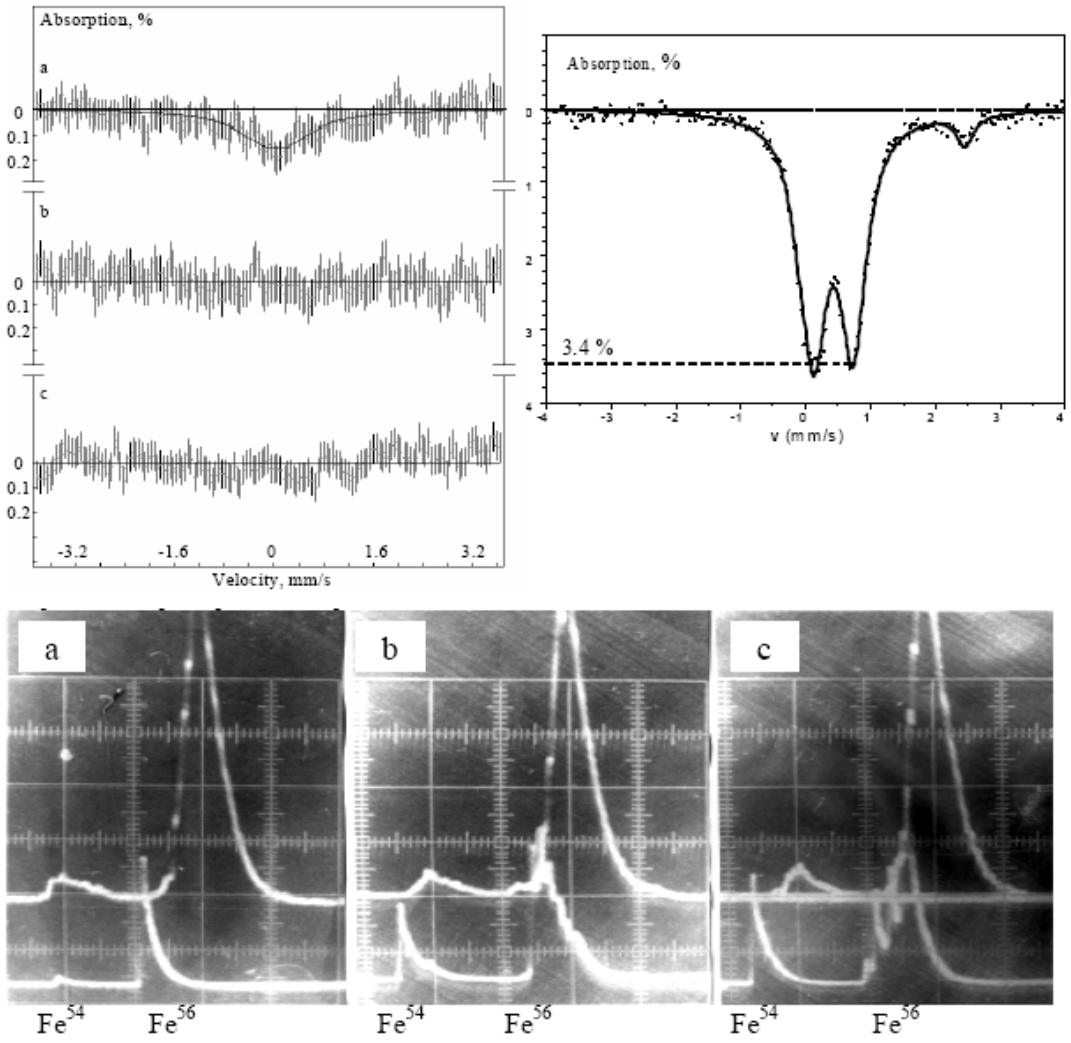


Figure 1. The top left is the Mössbauer spectrum of the dried microbiological culture of *Saccharomyces cerevisiae T-8*, grown in a liquid nutrient medium based on: (a) heavy water D_2O in the presence of the Mn^{55} isotope; (b) light water H_2O in the presence of Mn^{55}; (c) heavy water D_2O in the 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-

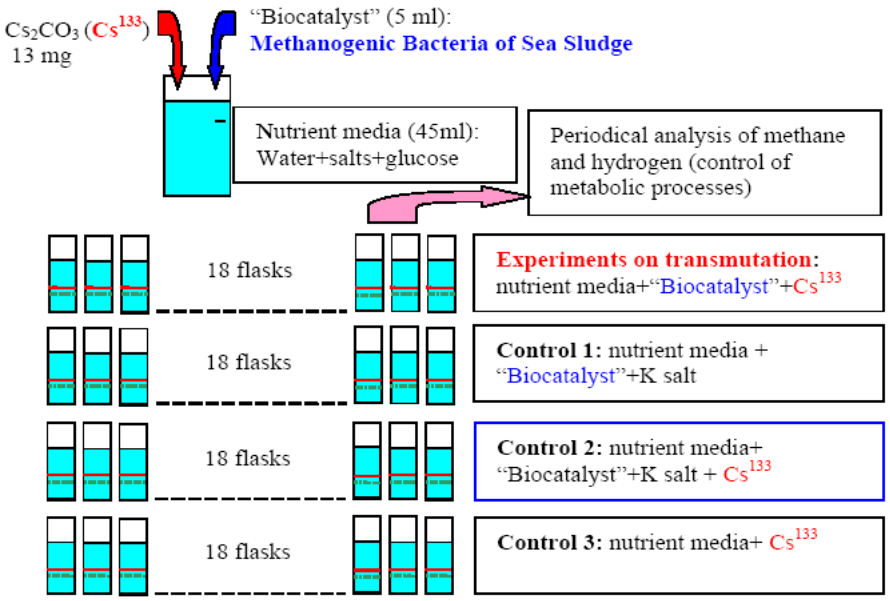


Figure 2. The scheme of experiments on transmutation of heavy stable isotopes by anaerobic cultures.

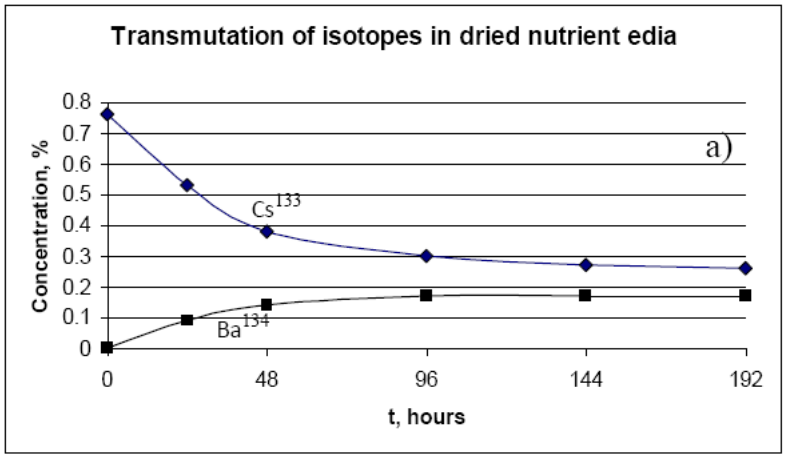
nutrients (including NH_4NO_3, $CaSO_4$, and $MgSO_4$), as well as stable cesium as the Cs_2CO_3 salt. But it did not contain potassium, which is vital for the growth of the organisms included in these associations. Barium is a biochemical analogue of potassium and in the absence of potassium, barium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

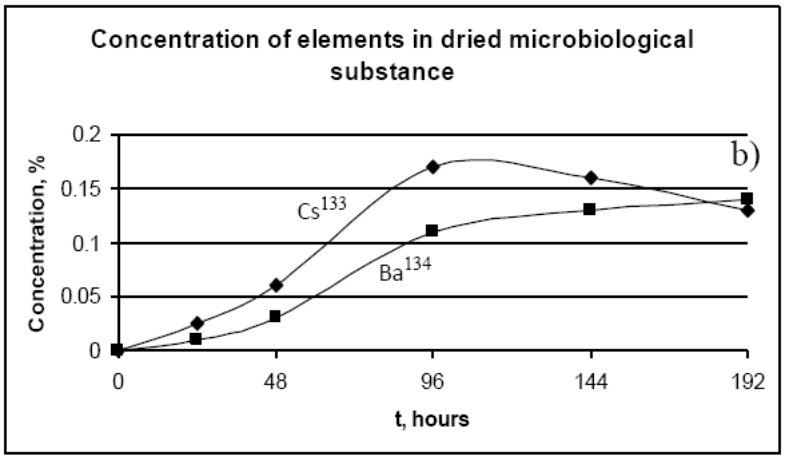
From these data it can be seen that in the process of growth of microbiological systems, there was continuous transmutation of cesium to barium, as well as partial absorption of cesium by growing microcultures (followed by a delayed transmutation into barium). This is especially evident in Fig. 3a, in 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 $(t = 0, \rho_{Cs^{133}} \approx 13\,\text{mg/cell})$ and final $(t = 192\,\text{h}, \rho_{Cs^{133}} \approx 6.5\,\text{mg/cell})$ 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 $\lambda = N(\text{Ba})/N(Cs^{133})\Delta t \approx 10^{-6}\ s^{-1}$ 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.

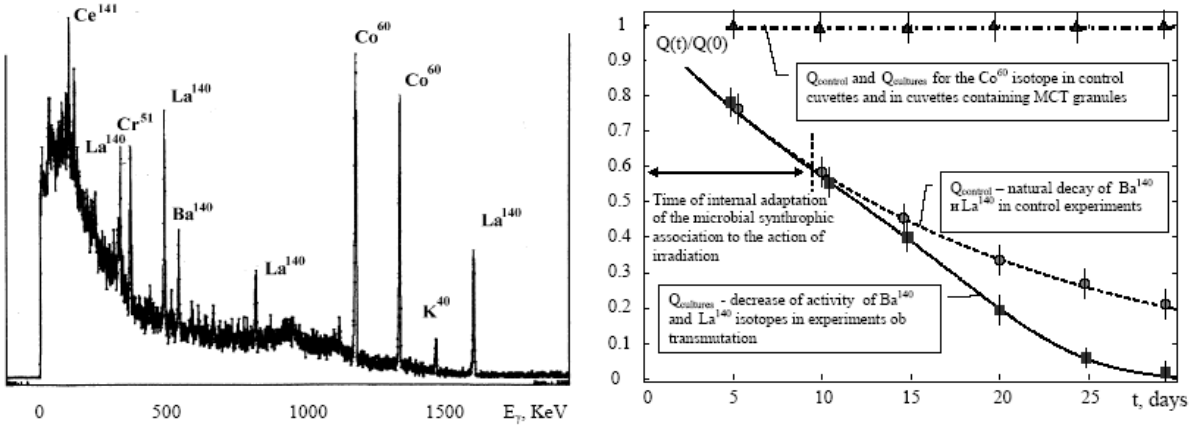


Figure 4. *Left*: spectrum of gamma-radiation of distilled water from the primary system of the light-water nuclear reactor. The data correspond to the 10th day after extracting a sample of the active water from the reactor. *Right*: the dependence of activity $Q(t)$ of Ba^{140}, La^{140} and Co^{60} 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

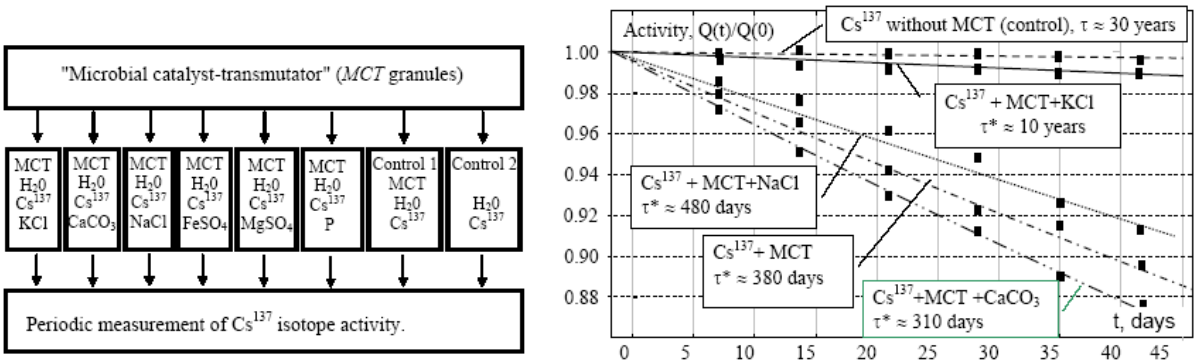


Figure 5. Scheme of studies of the utilization of Cs^{137} isotopes under different conditions and the results of experiments on the accelerated utilization (deactivation) of the Cs^{137} isotope in "biological cells" in the presence of MCT and various chemical elements.

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
($R_{\mathrm{Ba}} \approx 1.4$ Å, $R_{\mathrm{K}} \approx 1.33$ 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 $R_{\mathrm{Cs}} \approx 1.65$ –1.69 Å and potassium $R_{\mathrm{K}} \approx 1.33$ 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.

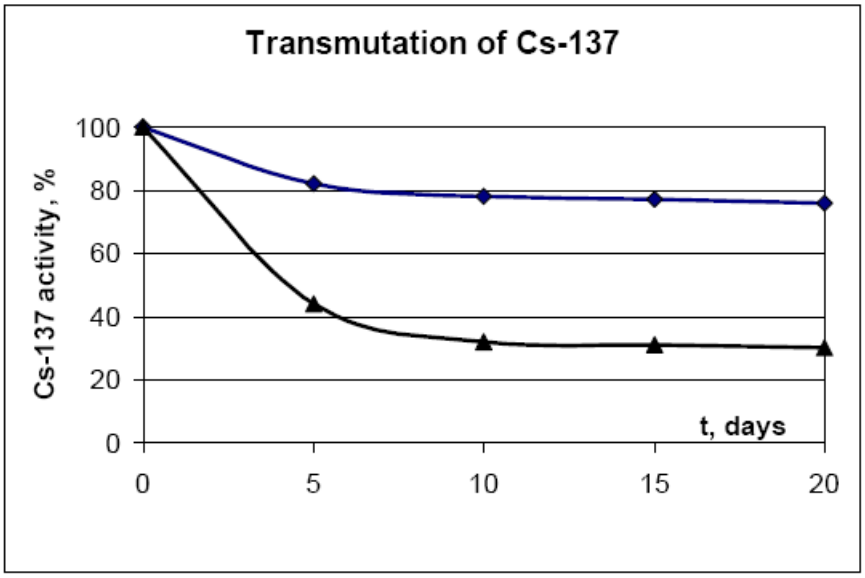


Figure 6. Reduction of gamma-activity of Cs^{137} aqueous solution in the optimized syntrophic association. The upper graph is the average data for the series of experiments, the lower is the similar reduction at the most optimal conditions from the same series.

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 $L \approx 2...4$ 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 $G_{\rm pq}, G_{\rm Et} \geq 10^3 - 10^4$ 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, $\delta t \geq G_{\rm Et}\hbar/2\delta E \approx 10^{-17} - 10^{-18}$ 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.

Acknowledgments

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Research Article

Biological Transmutations

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Abstract

For nearly 20 years, with many collaborators, I have studied biological transmutations, measuring the contents of seeds, bacteria, embryo cells and algae, before and after their growth. I have measured variations in their mineral composition indicating that it is very likely that transmutations occur in living systems.
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Keywords: Biological transmutations, Cold fusion, ICP, Kervran, Transmutations

1. Introduction

My interest in Biological Transmutations began in 1977 while I was a Post-doctorate at the Lawrence Berkeley Laboratory in California. I read a book mentioning the work of the French scientist Louis Kervran [1–6]. Not being a chemist, I kept this information in the back of my mind. But on March 23, 1989, came the announcement by Stanley Pons and Martin Fleischmann [7] of the discovery of Cold Fusion. I then realized that if chemistry can cause nuclear reactions, then biology could certainly do the same. In 1994, I met both Fleischmann and Pons at their laboratory in the South of France. I told them about Biological Transmutations, and to my surprise they were already aware of it.

When I started experimenting with Cold Fusion, I discovered physical instruments capable of doing chemical analysis without the need for test tubes, in particular Inductively Coupled Plasma-Atomic Emission Spectroscopy (ICP-AES) and Inductively Coupled Plasma-Mass Spectroscopy (ICP-MS) instruments. As soon as possible I performed several experiments with seeds and bacteria of all kinds to check the reality of Biological Transmutations. This paper reviews the 20 years of research that I have done in collaboration with several people. For readers interested in knowing the history of the field, I suggest a review paper that I published in the *Journal of Condensed Matter Nuclear Science* [8,9]. Some of the experiments were performed with a small number of samples, so that the error bars are too large to make sure that transmutation really occurred, but the large amount of experiments showing chemical and isotopic anomalies tend to demonstrate the validity of biological transmutations.

Two types of analysis have been performed. The first is ICP-AES, which allows quantitative chemical analysis. The second is ICP-MS, which allows isotopic analysis. This second technique is very important, because it reduces

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the need for a large number of samples. When you analyze the chemical composition of any sample, there are always variations between identical samples coming from the same batch. This is why it is necessary to multiply the number of samples in order to average the measurement uncertainties. With the isotopic analysis a single sample has value, because the precision of the measurement depends only on the sample itself. If the variation in comparison to the natural composition is large enough, then this measurement is valid with only one sample.

2. General Experimental Procedure

The same experimental procedure was used for all the experiments with seeds as well as with bacteria. A typical experiment is performed as follows: A growth medium is divided into two identical volumes. In both volumes, a given quantity of seed material is added, then a volume of nitric acid is added to the first volume to mineralize it. The second volume is kept under growth conditions. When growth is finished, the same amount of nitric acid is added to mineralize it. If no transmutation occurs, then both volumes should have the same mineral composition. Since we operate in open air, we do not analyze gases like hydrogen, oxygen, or nitrogen or even carbon which could vary in quantity by absorption of air gases. Analysis was performed by either ICP-AES or ICP-MS when available. Before and after comparisons were done to check for variations.

3. Wheat Seeds

Wheat seeds were grown in light water and heavy water. The analysis was done by ICP-AES and ICP-MS. Four different experiments were performed.

In the first experiment, wheat seeds were grown in distilled water and analyzed for silicon, calcium and magnesium contents. Analysis of the seeds compared to the sprouts was performed by ICP-AES. Table 1 shows the relative variation of these elements :

Table 1. Variation of Si, Ca and Mg during germination of wheat seeds measured by ICP-AES.

Elements	Variation (%)
Si	+8
Ca	–14
Mg	–5

We observe here an increase of silicon and a decrease of calcium and magnesium.

In a second set of experiments, wheat seeds were germinated in light water and heavy water. The first batch in light water germinated well, whereas the second batch in heavy water barely germinated. The analysis was performed by

Table 2. Isotopic distribution of Li, Mg and Cu during germination of wheat seeds in light and heavy water.

Elements	Atomic mass	Natural abundance (%)	Seeds (%)	Sprouts (%) in H_2O	Sprouts (%) in D_20
Li	6	7.5	7.9	11.2	6.5
Li	7	92.5	92.1	88.8	93.5
Mg	24	78.6	76.6	77.5	78.9
Mg	25	10.1	10.6	10.4	9.5
Mg	26	11.3	12.8	12.1	11.6
Cu	63	69.1	65.8	68.4	69.7
Cu	65	30.9	34.2	31.6	30.3

ICP-MS, in order to detect any isotopic anomaly. Table 2 shows the isotopic distributions of lithium, magnesium and copper:

It is interesting to note that wheat seeds sprouted in light water show an anomaly in the lithium mass distribution: Li-6 is 40% larger than in nature, but no change when grown in heavy water (which is not surprising since the growth was very bad). For magnesium and copper, there are variations, but they are not significant.

In a third set of experiments, wheat seeds were grown in heavy water. The following variations in concentration have been observed by ICP-MS and confirmed by ICP-AES as shown in Table 3.

Table 3. Variation of Be, Na, Mg and Pd during germination of wheat seeds measured by ICP-AES and ICP-MS.

Elements	Variation (%)
Be	+50
Na	+600
Mg	–30
Pd	–80

In a fourth set of experiments, wheat seeds were grown in light water. Results are shown in Table 4.

Table 4. Variation of Ca, Mg, Mn, K, P, B, Al, Si, Fe, Zn, K and Cu during growth of wheat seeds measured by ICP-AES.

Elements	Variation (%)	Variation (mg/ppb)
Ca	+5	+2mg
Mg	+3	+3mg
Mn	0	0
K	+4	+12mg
P	+3	+10mg
B	0	0
Al	–15	–80ppb
Si	–50	–5.2mg
Fe	–2	–0.1mg
Zn	+4	+0.2mg
K	+5	+12mg
Cu	–22	–185ppb

There are discrepancies between Table 1 and Table 4 since both experiments were performed under similar conditions: wheat seeds in light water and ICP-AES analysis. In Table 1, we observe a decrease of Ca and Mg and an increase of Si whereas in Table 4 we measure the exact opposite: increase of Ca and Mg and decrease of Si! This indicates either that the precision of the analysis is not good enough and that there is no change in composition, or as Kervran [1–6] pointed out, the reactions are reversible, and can change according to the growth conditions. Growth of seeds is never identical between one experiment and another.

4. Oat Seeds

Oats seeds are difficult to germinate. However, we have analyzed a set of seeds and an equivalent set of sprouts grown in light water, by ICP-MS. See Table 5.

Table 5. Variation of Hg, Zr and Pd during during germination of oat seeds measured by ICP-MS.

Elements	Variation (%)
Hg	–2000
Zr	–700
Pd	–300

Even though these are trace elements, it is interesting to observe here a large decrease of heavy metals during germination of oats seeds.

5. Marine bacteria (Marinobacter sp strain CAB)

Marine Bacteria were grown in a culture medium containing the following minerals; K, Mg, Na and Ca. Three experiments were performed.

The first set of experiments was performed with two samples of each. Table 6 shows the variation of the major minerals both in percentage and in weight.

Table 6. Variation of Na, Mg, K and Ca during development of Marine Bacteria measured by ICP-AES.

Elements	Variation (%)	Variation (mg)
Na	–10	–250
Mg	–5	–40
K	–22	–22
Ca	+17	+45

In addition to the analysis of the major components, trace elements have been also measured. Table 7 shows the relative variation of these metals.

Table 7. Variation of trace elements of Zn, Fe, Mn, Li and Cu during development of Marine Bacteria measured by ICP-AES.

Elements	Variation (%)
Zn	+33
Fe	+100
Mn	+100
Li	+53
Cu	+72

A second set of experiments has been performed with five samples of each. Table 8 shows the variation of the major minerals. No analysis of the trace elements has been made.

A third set of experiments with three samples and three blanks showed somewhat different results as shown on Table 9:

Table 8. Variation of Na, Mg, K and Ca during development of Marine Bacteria measured by ICP-AES

Elements	Variation (%)	Variation (mg)
Na	–2	–50
Mg	–4	–30
K	0	0
Ca	+9	+24

Table 9. Variation of Na, Mg and Ca during development of Marine Bacteria measured by ICP-AES.

Elements	Variation (%)
Na	–20
Mg	–1
Ca	–5

All three experiments show a decrease of Na and Mg, whereas Ca has increased in the first two experiments and decreased in the third one. The same comments as the one for wheat applies here: these discrepancies that may indicate a reversible reaction.

6. Lactobacillus

Lactobacillus bacteria were developed in a Rogosa medium. The following elements were analyzed by ICP-AES: Na, Mg, K, Ca, Mn and Fe. The relative variations of the minerals are listed in Table 10.

Table 10. Variation of Na, Mg, K, Ca, Mn and Fe during development of Lactobacilius bacteria measured by ICP-AES.

Elements	Variation (%)
Na	–2
Mg	–5
K	–5
Ca	+20
Mn	–4
Fe	–3

We observe here a large increase of Ca and a decrease of Na, Mg, K, Mn and Fe.

7. Mice Embryo Cells

A first set of experiments was performed. Mice embryo cells were developed in the Dulbecco's Modified Eagle's Medium. The variation of some of the measurable elements are listed in Table 11.

A second set of experiments was performed, the results are shown in Table 12. We observe an increase of five elements, and no decrease.

Table 11. Variation of Fe, K, Ca and Mg during development of mice embryo cells measured by ICP-AES.

Elements	Variation (%)
Fe	+19
K	+21
Ca	+13
Mg	+18

Table 12. Variation of Na, K and Ca during development of mice embryo cells measured by ICP-AES.

Elements	Variation (%)
Na	+5
K	+4
Ca	+6

8. Algae Spirulina

The growing medium included the following elements: Na, K, Mg, P, B, Zn, Mo, Mn and Fe. Six samples were used as blanks and six as active. The analysis of these elements is shown in Table 13.

Table 13. Variation of B, Mn, Na, K, Fe, Zn and Mg during development of Algae Spirulina measured by ICP-AES.

Elements	Variation (%)
B	+265
Mn	+41
Na	+9
K	+4
Fe	–7
Zn	–7
Mg	–14

9. Discussion

The whole field of Biological Transmutations makes no sense considering what we know about nuclear physics. There are several issues: first, how can we imagine two heavy nuclei fusing or a heavy nucleus fissioning in a living cell at room temperature? This is obviously against everything we know now. Second, if that much mass is involved in nuclear reactions, a lot of energy should be generated, but we do not see it. My work and also the work of other scientists show that transmutations occur in living cells. The results of this work are not sufficient to prove that Biological Transmutations really occurring, but there are many indications that it is happening.

10. Conclusion

The preliminary results reported in this work confirm previous results by Kervran: decrease of some elements and increase of others. Also, new information is shown: an important decrease of heavy mass metals during germination of seeds (wheat and oat). More work needs to be performed in order to verify these observations.

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Research Article

Nuclear Transmutations and Stabilization of Unstable Nuclei in the Cold Fusion Phenomenon*

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Abstract

We summarize the nuclear transmutations observed in the cold fusion phenomenon (CFP) putting a weight on the biotransmutation, i.e. nuclear transmutations in biological systems. The CF materials, i.e. materials where occurs the CFP, are classified into three groups: (1) the metallic material includes transition-metal hydrides (e.g. NiH_x, AuH_x) and deuterides (e.g. PdD_x, TiD_x), (2) the carbonic material includes hydrogen graphite (HC_x) and cross-linked polyethylene (XLPE) and (3) the biological material includes microorganisms, microbial cultures and biological tissues or organs. We explain these characteristics briefly in this paper. The stabilization of unstable nuclei, including the decay-time shortening of radioactive nuclei, in the nuclear transmutation is especially interesting from the applicatory point of view in relation to the treatment of the hazardous nuclear waste accompanied to the nuclear power plant. A characteristic of biological systems where occurs selective adsorption of specific ions seems especially useful for the application. If we have a microorganism or microbial culture absorbing an ion of a radioactive element selectively, we can remediate the radioactivity by the biotransmutation.
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Keywords: Actinoid, Biotransmutation, Cold fusion phenomenon, Meta-analysis, Microorganism, Nuclear transmutation, Transition metal

1. Introduction

Almost 30 years have elapsed since the discovery of the cold fusion phenomenon (CFP) in $PdDx$ by Fleischmann et al. in 1989 [1]. It should be kept in mind that hitherto we observed the CFP only in solids but not in liquids among condensed matter including a great deal of hydrogen isotopes (protium and/or deuterium). We may be able to classify the solids where the CFP (CF materials) have been observed into three groups according to the properties of host materials: (1) Metallic material including transition-metal hydrides (e.g. $NiHx$, $AuHx$) and deuterides (e.g. $PdDx$, $TiDx$). (2) Carbonic material including hydrogen graphites (HCx) and cross-linked polyethylene (XLPE). (3)

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Biological material including microorganisms, microbial cultures and biological organs. Each of the CF materials in these groups are composed of a super-lattice with a sublattice of host elements and another of hydrogen isotopes and have characteristics in the nuclear transmutations occurring there.

It should also be noted that we have observed the CFP only in these CF materials in dynamic conditions, not static conditions. This characteristic may be related to the complexity supposed to be in the CF materials ([2,3], Section 3.8).

It is also a remarkable characteristic of the CFP that there is a threshold value x of the average density of hydrogen isotopes in the CF materials for the occurrence of the CFP. The threshold value $x/X|_{\rm th}$ of the ratio x vs. X (the density of host element X) must be ≈ 0.8 or larger (in the case of transition metal hydrides and deuterides where $X =$ Ti, Ni, Pd and so forth).

These characteristics should be kept in mind when we look for the causes of the CFP based on the experimental facts obtained in this field.

It is interesting to see the ubiquitous appearance of the CFP in various CF materials as shown in Table 1.

Another characteristic of the CFP is that no gamma radiation is observed accompanying to the nuclear reactions producing transmuted nuclei, contrasting to the cases in free space where radiation such as gamma, beta and alphas are always observed.

It is natural to assume the participation of neutrons in nuclear reactions in CF materials with characteristics described above; it is common sense in nuclear physics to assume participation of neutrons to explain the occurrence of nuclear reactions in CF materials. We have proposed a model (TNCF model and its extended version, the Neutron Drop model) with an adjustable parameter to explain the cold fusion phenomenon. We have been successful to give unified systematic explanation of diverse and complex experimental data in this field [4–7].

We have deduced the existence of the trapped neutrons assumed in the TNCF model by the quantum mechanical investigation of the neutron–proton (neutron–deuteron) interaction in CF materials [7]. The justification of existence of neutrons in the CF materials composed of a superlattice of host elements and hydrogen isotopes made the TNCF model evolve into the Neutron Drop model, an extended version of the former.

Table 1. System and obtained evidence of the CFP: Host solids, agents, experimental methods, direct and indirect evidence, cumulative and dissipative observables are tabulated. Q and NT express excess energy and the nuclear transmutation, respectively. Direct evidence of nuclear reactions in the CFP are dependences of reaction products on their energy (ε) and position (***r***), decrease of decay constants of radioactive nuclides, decrease of fission threshold energy of compound nuclei.

Host solids	C, Pd, Ti, Ni, Au, Pt, KCl + LiCl, $ReBa_2Cu_3O_{7,}Na_xWO_{3,}$ KD_2PO_4TGS (triglycine sulfate), $SrCe_aY_bNB_cO_d$, XLPE (cross linked polyethylene) and biological systems (microbial cultures)
Agents	n, d, p, $^{6}_{3}$Li, $^{10}_{3}$B, $^{12}_{6}$C, $^{39}_{19}$K, $^{85}_{37}$Rb, $^{87}_{37}$Rb
Experiments	Electrolysis, liquid contact, gas discharge and gas contact
Direct evidences of nuclear reaction	Gamma ray spectrum $\gamma(\varepsilon)$, neutron energy spectrum $n(\varepsilon)$, space distribution of NT products NT(***r***), stabilization of unstable nuclei (decrease of decay constants) and lowering of fission threshold energy
Indirect evidences of nuclear reaction	Excess energy Q, number of neutrons $N_{\rm n}$, amounts of tritium atom $N_{\rm t}$, Helium-4 atom* $N_{\rm He4}$, NT products (NT_D, NT_F, NT_A), X-ray spectrum X(ε)
Cumulative observables	NT(***r***), amount of tritium atom $N_{\rm t}$, helium-4* $N_{\rm He4}$
Dissipative observables	Excess energy$Q$, neutron energy spectrum $n(\varepsilon)$, number of neutrons $N_{\rm n,}$ gamma ray spectrum $\gamma(\varepsilon)$, X-ray spectrum X(ε)

It should be noticed that CF materials include biological systems. Nuclear transmutations in them were first observed more than 200 years ago ([5],Section 10.1, [8–10]. These biological systems have been cultivated recently to include microorganisms and microbial cultures [11,12] as shown in later sections.

We have to reconsider the roles of deductive and inductive logic in science at the beginning of 21st century when we have explored new situations in science over the last 20–30 years. It should also be noted that the analysis of experimental data should be reconsidered with the meta-analysis technique, which has been used effectively in modern medical science. We give a brief overview on this problem in this paper, leaving full discussions elsewhere.

It can be said that the roots of the fruitless battle fought between people in favor of CFP and those opposed to it can be summarized as follows. (1) Persistence to the deductive logic we have been accustomed to it since the dawn of modern science in 18th century, based on the linear dynamics. (2) Ignorance of the meta-analysis that is effective to analyze complicated data observed independently in similar samples by several researchers.

Since the development of non-linear dynamics, we have to realize the fact that the cause does not determine the effect in this real world where almost all phenomena are governed by non-linear dynamics. However, this fact has almost slipped out from our discussion on the reality of the CFP in almost 30 years.

In this paper, we concentrate our discussion on the biotransmutation and its application and leave detailed discussions on other nuclear transmutations to papers and books cited in the references.

2. Experimental Results on the Nuclear Transmutation and Stabilization of Unstable Nuclei in the Cold Fusion Phenomenon

Nuclear transmutations in the cold fusion phenomenon (CFP) occur in near-surface regions of the CF materials to a depth of a few micrometers. A wide variety of nuclear transmutation products occur, and we need to classify them by some standards to investigate them scientifically.

2.1. Nuclear transmutations in the CFP

Nuclear transmutations (NTs) are classified into four kinds, according to the mechanism that produces new nuclides from the original nuclei in the CF material: nuclear transmutation by absorption ($\mathrm{NT_A}$), nuclear transmutation by decay ($\mathrm{NT_D}$), nuclear transmutation by fission ($\mathrm{NT_F}$) and nuclear transmutation by transformation ($\mathrm{NT_T}$) in our model ([6], Section 2.6), [7], Section 2.5, [13]).

The stabilization of unstable nuclei (including decay-time shortening of unstable nuclei) observed in the CFP has been successfully explained mainly by the $\mathrm{NT_D}$ mechanism, although other mechanisms are not necessarily excluded. We will explain the stabilization of unstable nuclei in this paper along the lines of the explanation in our other papers for $\mathrm{NT_D}$.

2.2. Stabilization of unstable nuclei in the CFP

We have explained the stabilization of unstable nuclei (including decay-time shortening) in the CFP as follows ([7], Section 2.5.1.1, Decay-Time Shortening).

2.2.1. *Decay-time shortening*

In general, the explanation of the mechanisms of the nuclear transmutations by decay ($\mathrm{NT_D}$) with absorption of a neutron drop ${}^{A}_{Z}\Delta$ composed of Z protons and $(A-Z)$ neutrons are given by the following reaction formulae:

$$ {}^{A}_{Z}\Delta + {}^{A'}_{Z'}X \to {}^{A-m}_{Z}\Delta + {}^{A'+m}_{Z'}X^{*} \to {}^{A-m}_{Z}\Delta + {}^{A'+m}_{Z'+1}X' + \mathrm{e}^{-} + \underline{\nu_{\mathrm{e}}} + Q, \tag{1} $$

$$ {}^{A'+m}_{Z'}X^{*} \rightarrow {}^{A'+m}_{Z'+1}X' + \mathrm{e}^{-} + \underline{\nu_{\mathrm{e}}} + Q, \qquad (\beta), \tag{2} $$

$$ {}^{A'+m}_{Z'}X^{*} \rightarrow {}^{A'+m-4}_{Z'-2}X'' + {}^{4}_{2}\mathrm{He} + Q, \qquad (\alpha), \tag{3} $$

where α and β in parentheses designate types of the decay.

In these nuclear transmutations, there are several cases where the decay-times τ_{d} of the intermediate compound nuclide ${}^{A}_{Z}X^{*}$ in free space are very long, of the order of 10^{6} –10^{9} years (10^{12}–10^{15} s). The time elapsed in experiments is at most several months ($\approx 10^{5}$ s). Therefore, if the decay products with such long decay-times are observed, there should be drastic shortening of the decay-times (or stabilization of unstable nuclei).

The following compound nuclei correspond to this case:

$$ {}^{107}_{46}\mathrm{Pd}^{*} \rightarrow {}^{107}_{47}\mathrm{Ag}\,(\beta) \qquad (\tau_{\mathrm{d}} = 1.3 \times 10^{9}\,\text{years}), $$

$$ {}^{40}_{19}\mathrm{K}^{*} \rightarrow {}^{40}_{20}\mathrm{Ca}\,(\beta) \qquad (\tau_{\mathrm{d}} = \times 6.510^{6}\,\text{years}), $$

$$ {}^{235}_{92}\mathrm{U}^{*} \rightarrow {}^{231}_{90}\mathrm{Th}^{*}\,(\alpha) \qquad (\tau_{\mathrm{d}} = 1.0 \times 10^{9}\,\text{years}), $$

$$ {}^{238}_{92}\mathrm{U}^{*} \rightarrow {}^{234}_{90}\mathrm{Th}^{*}\,(\alpha) \qquad (\tau_{\mathrm{d}} = 6.5 \times 10^{9}\,\text{years}). $$

2.2.2. *Nuclear transmutation in actinoid hydrides and deuterides*

Experimental data sets on actinoid hydrides and deuterides prepared by electrolysis and glow discharge [14–16] have been analyzed and explained using the TNCF model [17]. The experimental data have shown that these hydrides and deuterides are classified as CF materials where CFP occur, and the observed events are understood by nuclear reactions common to other reactions observed in CF materials, mainly transition-metal hydrides and deuterides.

The changes of radiation properties of actinoids occluding hydrogen isotopes are explained by the formation of the CF-matter similar to the free neutron sea in neutron star matter [18], and then by the interaction of actinoid nucleus and the CF-matter. We have explained the experimental results [14–16] on the acceleration of the alpha decay of ${}^{238}_{92}\mathrm{U}$ into ${}^{234}_{90}\mathrm{Th}$, the so-called the decay-time shortening, by the change of the boundary layer between the nucleus ${}^{238}_{92}\mathrm{U}$ and the CF-matter. The change of the boundary layer is induced by the increase of the density ratio $n_{\mathrm{o}}/n_{\mathrm{i}}$ of neutrons (n_{i} and n_{o} are the neutron densities inside and outside the nucleus, respectively) due to the formation of the CF-matter ([19], Section 2.9).

A possible application of this phenomenon to ${}^{A}_{94}\mathrm{Pu}$ ($A = 238$–244) is hopeful.

If we can accelerate the decay of plutonium isotopes which are produced in atomic plants as hazardous waste, then it would be a tremendous help dealing with this waste, which is a serious, difficult, expensive problem. As shown in Table 2, plutonium isotopes have very long decay-times and therefore the decay-time shortening as shown in the CFP will be applicable to transmute them into other nuclides easy to treat.

Instead of neutron bombardment in free space, we can use CF-materials to produce the same effect of neutrons on target nuclei (cf. [20]). This fact may be interesting in the science and technology of neutron–nuclear interactions in the low energy region ([21], Section 3). It is a pleasant fantasy to imagine a machine that simultaneously remediates radioactive waste and generates excess energy.

Table 2. Decay characteristics of plutonium isotopes $^{A}_{94}$Pu. Decay modes, half-life (years), decay heat (W/kg) and number of spontaneous fission neutrons (per g s) are given.

Isotope	Decay mode	Half-life (years)	Decay heat (W/kg)	Spon. fission n's (1/g s)
$^{238}_{94}$Pu	alpha to $^{234}_{92}$U	87.74	560	2600
$^{239}_{94}$Pu	alpha to $^{235}_{92}$U	24,100	1.9	0.022
$^{240}_{94}$Pu	alpha to $^{236}_{92}$U+ Spont. Fission	6560	6.8	910
$^{241}_{94}$Pu	e^- to $^{241}_{95}$Am	14.4	4.2	0.049
$^{242}_{94}$Pu	alpha to $^{238}_{92}$U	376,000	0.1	1700

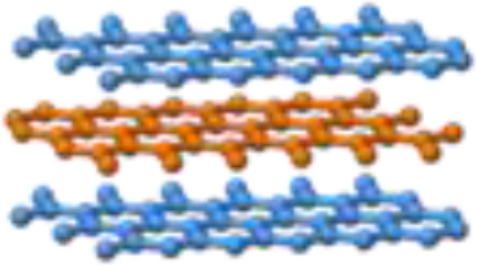


Figure 1. Side view of layer stacking of graphite (after Wikipedia).

2.3. Nuclear transmutation in hydrogen graphite HC_x ($x = 6$–8?)

We may then have a superlattice made of a carbon sublattice of graphite (Fig. 1) and a hydrogen sublattice occluded between carbon layers in the graphite. The HC_x superlattice may have a structure similar to the superlattice CaC_6 shown in Fig. 2. If the hydrogen graphite HC_x forms such a superlattice considered above, it forms the CF-matter which participates in the CFP by the mechanism proposed in our books ([2,7], Section 3.7) and [6,22]. Thus, the product elements observed in the system of carbon arc in water are explained by our TNCF model as a result of the nuclear transmutation catalyzed by the trapped neutrons ([3], Section 3.7). The product elements observed in carbon arcs include the following elements in addition to the most abundant iron (Fe); Si, S, Cl, K, Ca, Ti, Cr, Mn, Co, Ni,

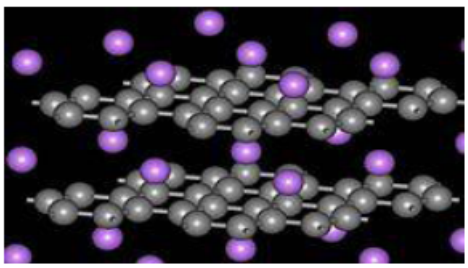
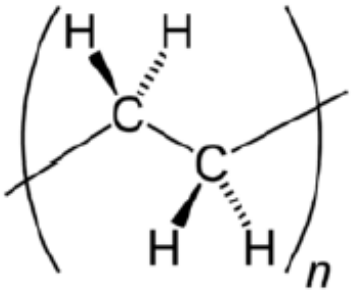
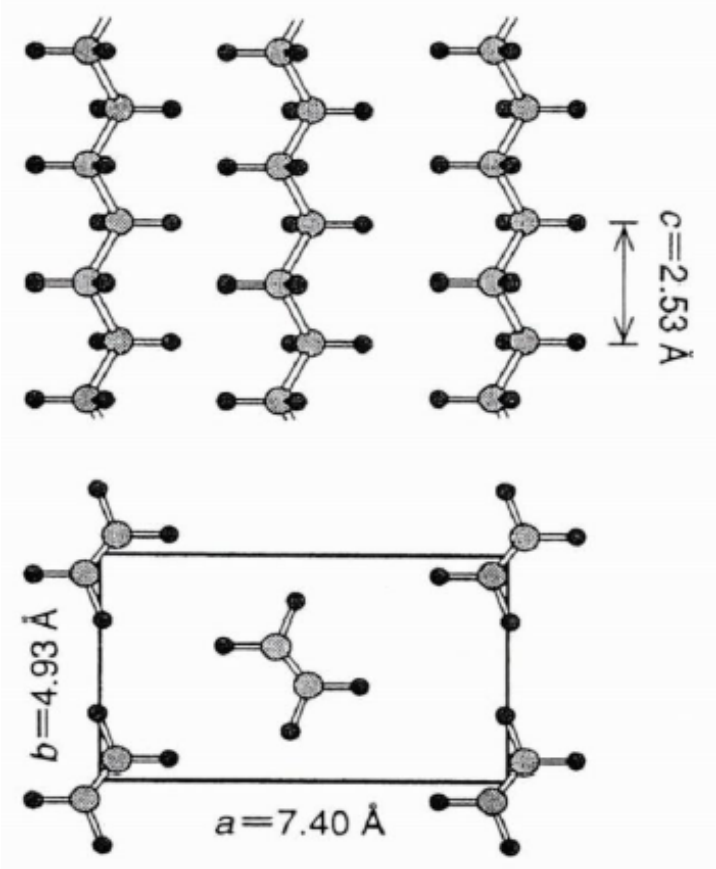


Figure 2. Structure of CaC_6: violet spheres represent Ca nuclei between layers of carbon nuclei (grey spheres) (after Wikipedia). We may imagine the structure of hydrogen graphite HC_x ($x = 6$ to 8 ?) which is not determined yet referring to this structure of CaC_6.



(a)



(b)

Figure 3. (a) Unit of polyethylene $(C_2H_4)_n$ ($n = \infty$). (b) Lattice structure of XLPE orthorhombic lattice with attice constants, $a = 7.40$ (740 pm), $b = 4.93$ (493 pm) and $c = 2.53$ (253 m) ([23], Fig. 5).

Cu, Zn and possibly heavier elements [3].

2.4. Nuclear transmutation in XLPE

Similarly, we can contemplate the appearance of neutron bands in XLPE shown in Fig. 3 [23]. The rather regular structure of the carbon–hydrogen array in XLPE suggests a similar mechanism to form the neutron bands as discussed in our recent papers [22,23]. The atomic arrays in biological cells are more complex than those of XLPE, as explained in Section 3, but we may be able to use the same idea used in the CFP general in biological systems.

Then, we can explain the nuclear transmutations in XLPE observed by the excellent experiments performed by Kumazawa et al. for more than 10 years starting in 2005, described in our papers [22,23]. For the illustration of nuclear transmutations in their systems including XLPE, see Table 3 from our paper [23], Table 2).

Table 3. Increase (+) and decrease (–) of inorganic elements in samples after voltage application (Table 2 of [23]).

Element	Isotopes	Sample		
		Dipped in KCl solution	Dipped in NaCl solution	Dipped in $AgNO_3$ solution
$_{3}$Li	^{6}Li, ^{7}Li			+
$_{11}$Na	^{23}Na		−	(+)
$_{12}$Mg	^{24}Mg, ^{25}Mg, ^{26}Mg		−	
$_{13}$Al	^{27}Al		+	
$_{19}$K	^{39}K, ^{40}K, ^{41}K	−		
$_{20}$Ca	^{40}Ca, ^{42}Ca, ^{43}Ca, ^{44}Ca, ^{46}Ca, ^{48}Ca	+		
$_{26}$Fe	^{54}Fe, ^{56}Fe, ^{57}Fe, ^{58}Fe			−
$_{28}$Ni	^{58}Ni, ^{60}Ni, ^{61}Ni, ^{62}Ni, ^{64}Ni			+
$_{47}$Ag	^{107}Ag, ^{109}Ag			(−)
$_{82}$Pb	^{204}Pb, ^{206}Pb, ^{207}Pb, ^{208}Pb			+
$_{83}$Bi	^{209}Bi			+

3. Characteristics of Biotransmutation

Applying the TNCF model to the problems of biotransmutation, we can use following reactions between a trapped neutron n and a nucleus ${}^{A}_{Z}X$ at or in the surface of a bacterium or a tissue [24]:

$$ {}^{A}_{Z}X + n \rightarrow {}^{A+1}_{Z}X^{*}. \tag{4} $$

In this reaction formula, ${}^{A+1}_{Z}X*$ is an excited state of the nucleus ${}^{A+1}_{Z}X$ which will decay through following several channels in free space:

$$ {}^{A+1}_{Z}X^{*} \rightarrow {}^{A+1}_{Z}X + \gamma, \tag{5} $$

$$ \rightarrow {}^{A+1}_{Z+1}Y + \mathrm{e}^{-} + \underline{\nu_{\mathrm{e}}}, \tag{6} $$

$$ \rightarrow {}^{A+1}_{Z-1}Y' - \mathrm{e}^{-}, \tag{7} $$

$$ \rightarrow {}^{A-4}_{Z-2}Y'' + {}^{4}_{2}\mathrm{He}, \tag{8} $$

where ν_{e} is an anti-particle of the electron neutrino, γ is a photon (in free space) and Y, $Y'a$nd Y'' are daughter nuclides of the reactions. In the CF materials, the *photon* γ in the free space is supposed to be absorbed by the CF-matter formed of neutrons in the neutron band and its energy dissipates in *phonons* to heat the system as a whole ([7], Section 3.7.5).

3.1. Recent experimental data on the biotransmutation obtained by Vysotskii et al. [25,26]

Vysotskii and his collaborators have performed sophisticated experiments and obtained refined data sets in biological systems over the last 20 years, mainly by as cited in our paper [24]. To bring about the complex structure of microorganisms and microbial cultures used in their experiments, we produce their fundamental structures shown in Fig. 4. The structure of cell walls in microbial cultures depicted in Fig. 4(c) show complex but similar regular structures to that in XLPE shown in Fig. 3.

There are data sets showing (1) production of ${}^{57}_{26}$Fe from ${}^{55}_{25}$Mn and also (2) acceleration of the decay of radioactive nucleus ${}^{157}_{55}$Cs, ${}^{140}_{56}$Ba and ${}^{140}_{57}$La in several bacterial cultures.

Experiments were conducted using several bacterial cultures (*Bacillus subtilis GSY 228, Escherichia coli K-1, Deinococcus radiodurans M–1*) as well as the yeast culture *Saccharomyces cerevisiae T–8*. 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 *Deinococcus radiodurans M–1* in transmutation processes given the presence of powerful radioactive fields, as was noted earlier [26].

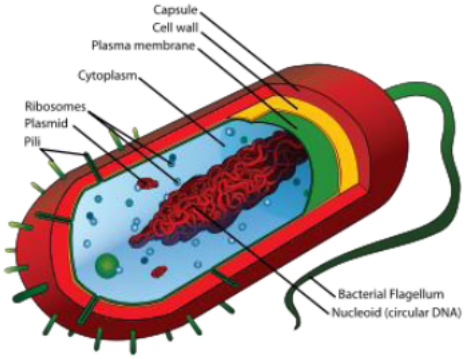
3.1.1. *Production of ${}^{57}_{26}$Fe in a CF material containing ${}^{55}_{25}$Mn*

An example of transmutation is the production of ${}^{57}_{26}$Fe in a CF material containing ${}^{55}_{25}$Mn. The nuclear reaction responsible to this case is suggested by Eqs. (5) and (6). We can explain the production of ${}^{57}_{26}$Fe from ${}^{55}_{25}$Mn by the following reactions based on the TNCF model [24], Section 3.1):

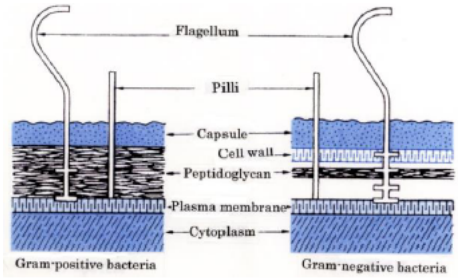
$$ {}^{55}_{25}\mathrm{Mn} + \mathrm{n} \rightarrow {}^{56}_{25}\mathrm{Mn}^{*} \qquad (\sigma = 13.41\ \mathrm{barn}), \tag{9} $$

$$ {}^{56}_{25}\mathrm{Mn}^{*} \rightarrow {}^{56}_{26}\mathrm{Fe} + \mathrm{e}^{-} + \underline{\nu_{\mathrm{e}}} \qquad (\tau = 2.5785\ \mathrm{h}), \tag{10} $$

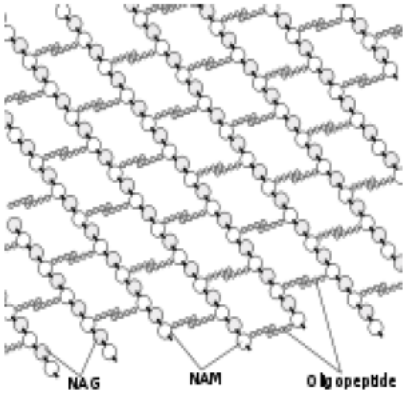
$$ {}^{56}_{26}\mathrm{Fe} + \mathrm{n} \rightarrow {}^{57}_{26}\mathrm{Fe} \qquad (\sigma = 2.5914\ \mathrm{barn}). \tag{11} $$



(a)



(b)



(c)

Figure 4. (a) Cell structure of a gram positive bacterium, (b) structures of cell walls in gram-positive and gram-negative bacteria and (c) structure of peptidoglycan (after Wikipedia).

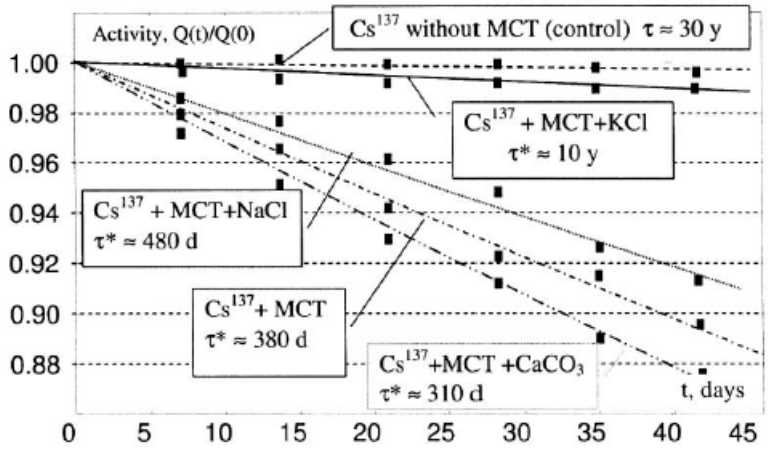


Figure 5. Accelerated deactivation (accelerated decay) of $^{137}_{55}$Cs isotope in "biological cells" with different chemical elements present ([25], Fig. 3.23, [26], Fig. 10). "MCT" in the explanation of this figure means the microbial transmutation catalyst, a special kind of granule.

3.1.2. *Decay-time shortening in biological system*

The observed acceleration of the decay process of $^{137}_{55}$Cs isotope is shown in Fig. 5. The behavior of the decay-time shortening in transition-metal hydrides had been noticed before and discussed in our paper already [13].

Another example of decay-time shortening in the biological system is obtained in $^{140}_{56}$Ba and $^{140}_{57}$La in pure reactor water with presence of metabolically active microorganisms as shown in Fig. 6.

3.2. Explanation of stabilization of unstable nuclei (or decay-time shortening) in biological system

The sophisticated experiments performed by Vysotskii et al. on the nuclear processes in biological systems revealed the existence of the decay-time shortening observed already in inorganic CF systems as discussed recently in our paper [24]. There are two examples of the decay-time shortening in biological system; one for $^{37}_{55}$Cs in electrolytic liquid, microbial catalyst-transmutator (MCT) + electrolyte (KCl, NaCl, or $CaCO_3$), and another for $^{140}_{56}$Ba and $^{140}_{57}$La in electrolytic liquid (water + metabolically active microorganisms). An explanation of MCT used in the experiment is given elsewhere [24].

3.2.1. $^{37}_{55}Cs$

The second example is the decay-time shortening of radioactive isotope $^{137}_{55}$Cs which decays in free space according to the following reaction shown in Fig. 5:

$$^{137}_{55}\mathrm{Cs} \rightarrow ^{137}_{56}\mathrm{Ba} + \mathrm{e}^- + \underline{\nu_\mathrm{e}} \qquad (\tau = 30.07 \text{ years}). \tag{12}$$

Assuming the existence of the trapped neutron in the TNCF model, we can apply Eq. (6) to this case:

$$^{137}_{55}\mathrm{Cs} + \mathrm{n} \rightarrow ^{138}_{55}\mathrm{Cs}^* \qquad (\sigma = 0.113 \text{ barn}), \tag{13}$$

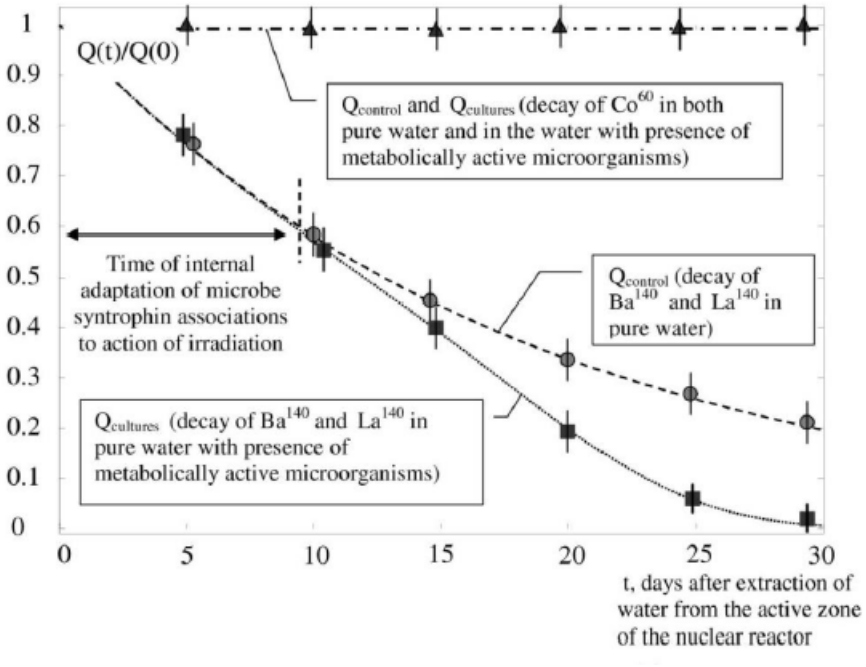


Figure 6. Change of activity Q(t) of the same reactor isotopes $^{140}_{56}$Ba, $^{140}_{57}$La and $^{60}_{27}$Co in the experiment on transmutation (activity Q_{cultures} in pure reactor water with presence of metabolically active microorganisms) and in the control one (activity Q_{control} in the same pure reactor water without microorganisms) ([25], Fig. 3.21, [26], Fig. 8).

$$^{138}_{55}\mathrm{Cs}^{*} \rightarrow ^{138}_{56}\mathrm{Ba} + \mathrm{e}^{-} + \underline{\nu_{\mathrm{e}}} \qquad (\tau = 33.41\ \mathrm{min}). \tag{14}$$

The difference of the effect of MCT + electrolyte (KCl, NaCl, or $CaCO_3$) on the decay-time shortening may reflect (1) a difference of the density of the trapped neutrons n_{n} or (2) a difference of the number of $^{137}_{55}$Cs nuclei on the MCT surface in the system due to the effect of electrolytic liquids (MCT + electrolytes) on the MCT.

The difference of measured decay times $\tau^{*} = 380$ days (MCT), 10 years (MCT + KCl), 480 days (MCT + NaCl), and 310 days (MCT + $CaCO_3$) compared to the natural decay time 30.1 years of $^{137}_{55}$Cs in free state shows the effect of the electrolytes on MCT where $^{137}_{55}$Cs nuclei are adsorbed and their decay characteristics are drastically influenced by the density of the trapped neutron in samples from our point of view. Thus, the electrolyte seems to have large effect on the adsorption characteristics of $^{137}_{55}$Cs by MCT.

This fact reminds us of the effect of K and Li on the CFP in Ni and Pd, which was discussed by us for many years ([28], Section 4, [7], Section 2.2.1.2).

"*It should be emphasized here that there is a preference for a combination of cathode metals (Pd, Ni, Ti, - -), an electrolyte (Li, Na, K, or Rb) and a solvent (D_2O or H_2O) to induce CFP.*" ([28], p. 45).

Let us investigate the characteristics of the decay-time shortening of $^{137}_{55}$Cs in these systems.

The temporal evolution of the number of a radioactive nuclide with a decay constant τ is described by following equations:

$$N(t) = N(0)\exp(-t/\tau), \tag{15}$$

$$\mathrm{d}N/\mathrm{d}t = -(N(0)/\tau)\exp(-t/\tau). \tag{16}$$

On the other hand, a decrease of the number of a nucleus ${}^{A}_{Z}X$ due to absorption of thermal neutrons described by Eq. (17) and relation (18) assumed in our model [5], Section 11.1), [7], Section 3.2):

$${}^{A}_{Z}X + \mathrm{n} = {}^{A}_{Z}X^{*} = {}^{A+1}_{Z}X + \text{phonons}, \tag{17}$$

$$P = \delta N_X/N_{\mathrm{X}} = 0.35\, n_{\mathrm{n}}\, v_{\mathrm{n}}\, \sigma_{\mathrm{nX}}. \tag{18}$$

In the above equations, n_{n} is the density of the trapped neutron, v_{n} is the thermal velocity of the assumed trapped neutron, N_X is the number of the nucleus ${}^{\mathrm{A}}_{Z}X$, and $\sigma_{\mathrm{n}X}$ is the absorption cross section of thermal neutrons by the nucleus X by reaction (17) ($\sigma_{\mathrm{nX}} = 0.113$ barn for ${}^{137}_{55}$Cs) assumed to be the same as the thermal neutron absorption cross section in free space. We use a value 2.2×10^5 cm/s for v_{n} according to our premises of the TNCF model.

If an ${}^{137}_{55}$Cs nucleus is adsorbed by the MCT granules to be reacted by the trapped neutron, reaction (17) is written down as

$${}^{137}_{55}\mathrm{Cs} + \mathrm{n} = {}^{138}_{55}\mathrm{Cs}^{*} = {}^{138}_{55}\mathrm{Cs} + \text{phonons}. \tag{19}$$

The reaction occurs with a probability P in a unit time interval for a nucleus ${}^{137}_{55}$Cs as expressed in Eq. (18):

$$P = \delta N_{\mathrm{Cs}}/N_{\mathrm{Cs}} = 0.35\, n_{\mathrm{n}}\, v_{\mathrm{n}}\, \sigma_{\mathrm{nCs}}. \tag{20}$$

Let us determine the density n_{n} of the TNCF model, assuming that the observed decay-time shortenings of ${}^{137}_{55}$Cs in electrolytic liquids depicted in Fig. 5 are the results of the neutron absorption described by Eq. (19).

As an example of our calculation, we take up the case of ${}^{137}_{55}$Cs in an electrolytic liquid with MCT + $CaCO_3$, where the observed decay time is $\tau^* = 310$ days. Using Eq. (16), we obtain the relative number of decayed nucleus in a unit time (1 day, for instance) as

$$\begin{aligned}\delta N/N &= -(1/\tau^*)\exp(-t/\tau^*)\\ &= -1/(310 \times 8.64 \times 10^4) = -1/2.68 \times 10^7\\ &= 3.73 \times 10^{-8}.\end{aligned} \tag{21}$$

In this calculation, note that the exponential factor exp (– t/τ^*) ≈ 1 and does not substantially contribute to the final result.

On the other hand, Eq. (20) gives n_{n} through the relative number of transmuted ${}^{137}_{55}$Cs nuclei $\delta N/N$ as:

$$\begin{aligned}n_{\mathrm{n}} &= (\delta N/N)/(0.35 \times 2.2 \times 10^5 \times 0.113 \times 10^{-24}) \times 1(s)\\ &= (\delta N/N)/(0.35 \times 2.2 \times 0.113 \times 10^{-19})\\ &= 1.15 \times 10^{19}(\delta N/N).\end{aligned} \tag{22}$$

Using the value of $\delta N/N$given in Eq. (21), we obtain the value of $n_{\rm n}$ in this case as

$$\begin{aligned} n_{\rm n} &= (\delta N/N)/(0.35 \times 2.2 \times 10^5 \times 0.113 \times 10^{-24}) \times 1(s) \\ &= (\delta N/N)/(0.35 \times 2.2 \times 0.113 \times 10^{-19}) \\ &= 1.15 \times 10^{19}(\delta N/N). \end{aligned} \tag{23}$$

If the number of $^{137}_{55}$Cs adsorbed by MCT granules and that not adsorbed are in the ratio $x : (1 - x)$, the calculation should be generalized to take into this fact. In the short time (e.g. 1 day) we are interested in, the number N_0 of $^{137}_{55}$Cs nuclei not adsorbed and therefore not influenced by the trapped neutron keeps its number $(1 - x)N_0$ almost the same as before (for the very long decay time of $\tau_0 = 30.1$ years):

$$\delta N/N|_1 = 0. \tag{24}$$

On the other hand, the nuclei adsorbed by MCT granules will suffer the action of the trapped neutron and its number xN_0 changes according to Eq. (20):

$$\delta N/N|_2 = 0.35\, n_{\rm n} v_{\rm n} \sigma_{\rm nM}. \tag{25}$$

Therefore, we have the change δN_0 of the number N_0 of $^{137}_{55}$Cs nuclei after the time interval t (= 1 day) given by $\delta N|_1$ due to the decay process (16) with $\tau = 30.1$ years and by $\delta N|_2$ due to the neutron trapping (20). Using relations (24) and (25), we obtain finally the expression for δN_0 /N_0 as given in Eq. (27):

$$\delta N_0 = \delta N|_1 + \delta N|_2 = \delta(1 - x)N_0|_1 + \delta x N_0|_2, \tag{26}$$

$$\delta N_0/N_0 = x(\delta N_0|_2/N_0) = x(0.35 n_{\rm n} v_{\rm n} \sigma_{\rm nM}). \tag{27}$$

Substituting the values $v_{\rm n} = 2.2 \times 10^5$ cm/s and $\sigma_{\rm nM} = 0.113$ barn, we obtain following equation:

$$\delta N_0/N_0 = x n_{\rm n}(0.35 \times 2.2 \times 10^5 \times 0.113 \times 10^{-24}) = 8.7 \times 10^{-21} x n_{\rm n}. \tag{28}$$

Therefore, the value $n_{\rm n}$ in this case is expressed as

$$n_{\rm n} = 1.15 \times 10^{19}(\delta N/N)x^{-1}({\rm cm}^{-3}). \tag{29}$$

If $x = 1$, i.e. all the $^{137}_{55}$Cs nuclei are adsorbed by MCT granules and influenced by the trapped neutron by Eq. (19), $\delta N/N = 3.73 \times 10^{-8}$ (21) gives the same value given in (23):

$$n_{\rm n} = 1.15 \times 10^{19}(\delta N/N)x^{-1} = 4.29 \times 10^{11}({\rm cm}^{-3}). \tag{30}$$

This value is compared with the values 10^7 – 10^{12} cm^{-3} obtained in inorganic CF materials given in our previous books ([5], Tables 11.2 and 11.3, [7], Tables 2.2 and 2.3).

As Eq. (16) (or Eq. (21)) shows that the decrease of the number of radioactive nuclei is proportional to the decay time τ* inversely and it is also proportional to x and $n_{\rm n}$ as shown in Eq. (27) (where x is the ratio of adsorbed nuclei). The differences of τ* observed in different electrolytic liquids are explained as follows.

If the density of trapped neutrons $n_{\rm n}$ is not influenced by the kind of electrolyte in the liquid, the difference of τ* depends only on the value of x which may depend on the electrolyte. The values of $\tau* = 310$, 380, 480 days, 10 years in the liquid with $CaCO_3$, non, NaCl, KCl, respectively, show that the ratios x in these electrolytic liquids are given by 1, 0.8, 0.6, 8.5 $\times 10^{-3}$, respectively taking the case of $CaCO_3$ as $x = 1$.

This result may show the aqueous solution of MCT granules is very effective at adsorbing a $^{137}_{55}$Cs nucleus (and change the value of x) and addition of $CaCO_3$ works positively but that of NaCl and KCl negatively to the adsorption, if our interpretation by the TNCF model of the decay-time shortening in the electrolytic liquids is right.

3.3. $^{140}_{56}$Ba and $^{140}_{57}$La

Similarly, we can analyze the cases of $^{140}_{56}$Ba and $^{140}_{57}$La shown in Fig. 6. The decay rates of these nuclides are described by the following formulae:

$$^{140}_{56}\mathrm{Ba} \rightarrow {}^{140}_{57}\mathrm{La} + \mathrm{e}^- + \underline{\nu_{\rm e}} \qquad (\tau = 12.752 \text{ days}), \tag{31}$$

$$^{140}_{57}\mathrm{La} \rightarrow {}^{140}_{58}\mathrm{Ce} + \mathrm{e}^- + \underline{\nu_{\rm e}} \qquad (\tau = 1.6781 \text{ days}). \tag{32}$$

The decay-time shortening of these nuclides is explained by the absorption of a neutron by $^{140}_{56}$Ba and $^{140}_{57}$La, followed by the beta-decay of the intermediate nuclei as shown:

$$^{140}_{56}\mathrm{Ba} + \mathrm{n} \rightarrow {}^{141}_{56}\mathrm{Ba}^* \qquad (\sigma = 1.63 \text{ barn}, \tag{33}$$

$$^{141}_{56}\mathrm{Ba}^* \rightarrow {}^{141}_{57}\mathrm{La} + \mathrm{e}^- + \underline{\nu_{\rm e}} \qquad (\tau = 18.27 \text{ min}) \tag{34}$$

and

$$^{140}_{57}\mathrm{La} + \mathrm{n} \rightarrow {}^{141}_{56}\mathrm{La}^* \qquad (\sigma = 2.73 \text{ barn}, \tag{35}$$

$$^{141}_{56}\mathrm{La}^* \rightarrow {}^{141}_{58}\mathrm{Ce} + \mathrm{e}^- + \underline{\nu_{\rm e}} \qquad (\tau = 3.92 \text{ h}). \tag{36}$$

On the other hand, the decay of $^{60}_{27}$Co is n intensified measurably by the existence and absorption of the trapped neutrons as shown by following equations:

$$^{60}_{27}\mathrm{Co} \rightarrow {}^{60}_{58}\mathrm{+e}^- + \underline{\nu_{\rm e}} \qquad (\tau = 10.47 \text{ min}), \tag{37}$$

$$^{60}_{27}\mathrm{Co} + \mathrm{n} \rightarrow {}^{61}_{27}\mathrm{Co}^* \qquad (\sigma = 2.02 \text{ barn}), \tag{38}$$

$$^{61}_{27}\mathrm{Co}^* \rightarrow {}^{61}_{58}\mathrm{Ni} + \mathrm{e}^- + \underline{\nu_{\rm e}} \qquad (\tau = 1.65 \text{ h}). \tag{39}$$

Thus, the experimental data sets obtained for $^{140}_{56}$Ba, $^{140}_{57}$La and $^{60}_{27}$Co shown in Fig. 6 are consistently explained by the TNCF model.

3.4. Other biotransmutations

Regarding the data on biotransmutations, some examples have been known since 18th century. Here are some quotes relating to our investigation, from page 25 of Michio Kushi's book [9]. The elemental transmutation (ET) in biological systems is considered as "most likely taking place at the cellular level."

"- - - it was concluded that, granted the existence of transmutations (Na to Mg, K to Ca, Mn to Fe), then a net surplus of energy was also produced."

"A proposed mechanism was described in which Mg adenosine triphosphate (MgATP) played a double role as an energy producer." "The MgATP, when placed in layers one atop the other, has all the attributes of a cyclotron."

"It was concluded that elemental transmutations were indeed occurring in life organs and were probably accompanied by a net energy gain." ([9], p. 25)

This summary of the biotransmutations by M. Kushi is based on many observations by Vauquelin and others which are introduced in our book ([5], Section 10.1, Biotransmutation).

3.5. Characteristics of biotransmutations applicable to the remediation of the hazardous nuclear waste

In inorganic systems used in CFP, it is known that there are specific favorable combinations of an electrode and an electrolyte to produce CFP in electrolytic experiments: Pd–Li and Ni–K are the most outstanding pairs used in positive experiments [27].

It might be possible to have a biological system in which the CF material (e.g. a bacterium) selectively adsorbs a specific element on the surface, depending on the nature of the surface or of the material. Then if the bacterium works as an agent similar to the MCT in Fig. 5, the system might effectively remediate hazardous radioactive waste.

4. Quantum Mechanical Bases of the Neutron Drop Model

It has been shown that our phenomenological approach by the TNCF model with an adjustable parameter (and by the neutron drop model) gives a consistent and unified explanation of almost all experimental results obtained in the CFP not only for deuterides but also for hydrides. Furthermore, we explained the CFP observed in hydrogen graphite and biological systems by the TNCF model.

We give a brief explanation of the TNCF and the ND models and explain quantum mechanical bases of these models.

4.1. TNCF model and neutron drop model

The original TNCF model was proposed in 1993 at ICCF4. It assumes the existence of quasi-stable neutrons in CF materials [4].

4.1.1. *A phenomenological approach to the CFP – the TNCF model and the neutron drop model*

We have proposed a unified explanation of various experimental data sets by the TNCF model introduced at ICCF4, and we published a book containing the results of analyses in 1998 [5]. In the original model, we assumed nuclear reactions induced by absorption of single neutron by a nucleus in the system. It was remarkable to note that the model could explain observed data of several quantities in an experiment consistently using only one adjustable parameter.

To explain the nuclear transmutations with large changes of proton and neutron numbers, we extended the TNCF model to the ND (neutron drop) model in which we assumed existence of neutron drops ${}^{A}_{Z}\Delta$ composed of $(A - Z)$

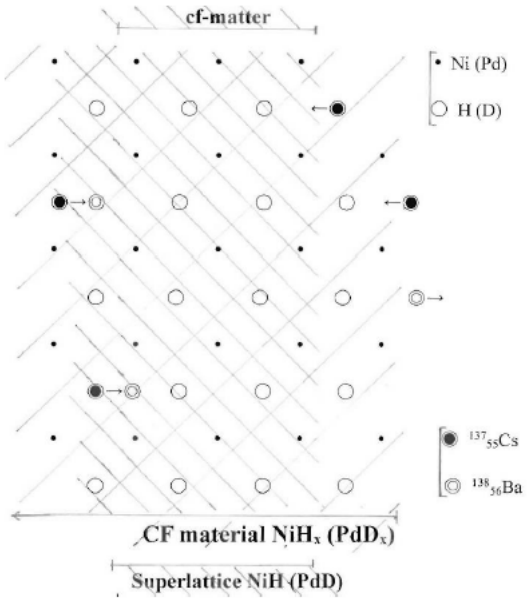


Figure 7. Schematic explanation of nuclear transmutations at the surface region of a CF material (e.g. NiH_x (PdD_x) in this figure). The nuclear transmutation explained in Section 3.2 (Eqs. (13) and (14)) is illustrated in this figure.

neutrons and Z protons suggested by the neutron star matter [18]. We named the state with neutron drops "CF-matter" for convenience in future discussions [7].

We have investigated the basis of trapped neutrons and neutron drops in such CF materials as transition metal deuterides and hydrides, using quantum mechanics on the interaction of host elements and hydrogen isotopes [6,7]. The schematic explanation of the CF material (e.g. NiH_x) at its surface region is shown in Fig. 7.

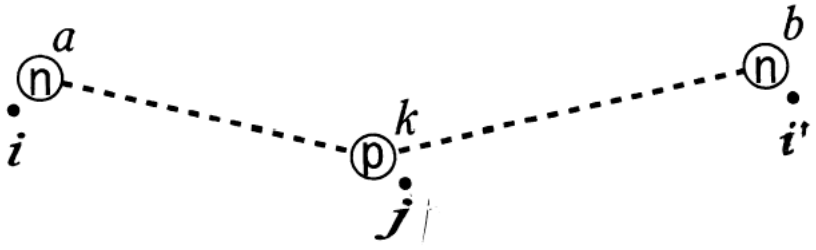


Figure 8. The super-nuclear interaction between two neutrons a and b in lattice nuclei $\boldsymbol{i}$ and $\boldsymbol{i}$' mediated by a proton (or a deuteron) k at an adjacent interstitial site $\boldsymbol{j}$ ([7], Fig. 3.3).

4.1.2. *Super-nuclear interaction of neutrons at lattice nuclei mediated by interstitial protons or deuterons*

The nuclear interaction between an interstitial proton (or deuteron) and a nucleus of the host elements on a lattice point (a lattice nucleus) induces the super-nuclear interaction between neutrons in different lattice nuclei when the interstitial proton (or deuteron) has an extended wavefunction reaching the lattice points as shown in Fig. 8 [7].

4.1.3. *Formation of the neutron bands and the CF-matter at boundary region*

The super-nuclear interaction results in the neutron bands and finally the CF-matter. The superlattice of the host elements and the hydrogen isotopes is an optimum structure to produce CF-matter [28].

The neutron waves in a neutron band are reflected at the boundary of the CF material and accumulate there as shown in Fig. 9.

The high density neutrons so created at the boundary region behave the same way as neutron star matter [18] and form the CF-matter ([7], Section 3.7.5). In the CF-matter, neutron drops ${}^{A}_{Z}\Delta$ may exist, as shown by the simulation for the neutron star matter [18].

4.1.4. *De-excitation of unstable nuclei by the interaction among particles in the CF-matter*

The mutual interactions among particles in CF-matter induces the de-excitation of lattice nuclei ${}^{A}_{Z}\mathrm{Y}^{*}$ at an excited state resulting in elevation of energies of the CF-matter ([7], Section 3.7.6). Finally, the elevated energy of the CF-matter is dissipated to lattice energy of the CF material, as explained below

4.1.5. *Neutron–phonon Interaction in CF-matter*

The neutron–neutron interaction mediated by interstitial protons or deuterons depends on the lattice sites $\boldsymbol{R}_{\mathrm{i}}$ of the relevant lattice nuclei. We have worked out the interaction formulae for the super-nuclear interaction at absolute zero where the lattice of host elements is at rest ([7], Sectin 3.7.1). The displacement of a nucleus ${}^{A}_{Z}\mathrm{X}$ at a lattice site $\boldsymbol{R}_{\mathrm{i}}$ by

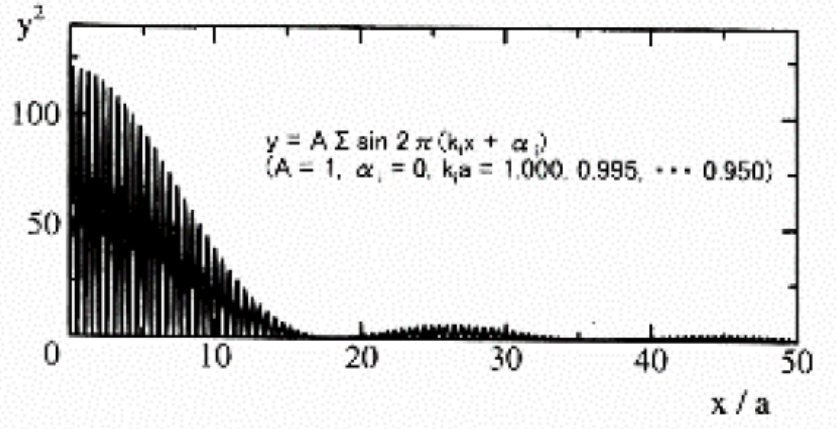


Figure 9. Neutron density accumulation of 11 neutrons reflected coherently at boundary. Abscissa is the distance in a unit of lattice constant $a$from the boundary where the neutron waves reflected. When a wave is reflected, the profile is a straight line at a height one parallel to the abscissa ([7], Fig. 3.4).

the lattice vibration at a finite temperature induces an interaction of neutrons in the neutron band and phonons of the lattice vibration.

This neutron–phonon interaction is responsible for the dissipation of neutron energy increased by the de-excitation of lattice nuclei. Thus, the emission of photons when the excited nuclei are de-excited in free space is alternatively resolved by the emission of phonons, as explained above. This mechanism explains the stabilization of unstable nuclei in the CF materials without emission of photons expected in free space.

4.2. Surface nature of nuclear reactions in the CFP

A superlattice of PdD is apt to be formed by self-organization at the surface region where the density of D is higher [28]. The super-nuclear interaction between neutrons results in the neutron bands and finally formation of CF-matter at boundary regions. The neutron drops $AZ\Delta$ in the CF-matter participate in the nuclear transmutations of foreign nuclei at the surface region as shown in Fig. 7 [7,28].

4.3. Non-linear dynamics and complexity in the CFP

The qualitative reproducibility and other characteristics of the CFP pointed out in the Introduction of this paper suggests that the complexity investigated extensively in the non-linear dynamics in recent years has close relation with physics of atoms and atomic nuclei in the CF materials. The three laws found in the CFP should have also close relation with the complexity in the CFP [29].

The three laws are as follows:

(1) The First Law: the stability effect for nuclear transmutation products.
(2) Second Law; the inverse power dependence of the frequency on the intensity of the excess heat production.
(3) Third Law: bifurcation of the intensity of events (neutron emission and excess heat production) in time.

We see that the second and the third laws have especially close connection with complexity. We investigated the relationship of complexity with the CFP in previous papers [28,30].

4.4. Inductive logic and meta-analysis in the CFP

Since the development of modern science in 16th century, physics developed according to the deductive logic guided by fundamental principles that govern simple systems following linear dynamics. The natural history used widely in science before the rise of modern science had been put aside as old-fashioned thinking.

However, we have to reconsider the logic useful in the investigation of nature. In nature, non-linear interactions are ubiquitous and therefore complexity prevails, as revealed by non-linear dynamics. Inductive logic should be effective to investigate phenomena occurring in complicated systems governed by non-linear interactions [31].

K. Nakamura, a molecular biologist, expressed her credo on the bio-history (natural history in biology) [32] leaving reductionism (based on the deductive logic) prevailed in the natural science since the beginning of the modern science in 17th century as follows:

"The history in Bio-history means a tale of history. I wanted to spin a story about the diverse nature based on the life. It was my object of research at present. In modern science, we have spent our time advancing toward a truth, and we have to write papers on results obtained independent of history. However, science is changing now. The time of exoscience, i.e. the science where the researcher is outside the objective system and describes the phenomena logically, objectively and universally, has gone. The so-called endoscience, i.e. the science where the researcher is in the system, is being born. Bio-history does not forbid modern science from going another way, but faithfully takes just its extended

way further. It seems to me that the science itself, including physics, is moving into endoscience now, in parallel to the transition of 'the time of reason' to 'the time of life'." ([32], p. 218)

It should also be noted that analysis of experimental data should be reconsidered in view of the history of science. The meta-analysis is widely used in medical science where there is a great deal of data not reproducible exactly, while we meet reproducibility in physical science of linear dynamics [33,34]. The problem in medical science is the same as in our investigation of the data for CFP [5,7]. We have to reconsider our problem from the general point of view as will be presented in our future papers [31,35].

We cite here several sentences related to the definition and considerations on the meta-analysis.

The meta-analysis is defined as follows:

"It is possible to define the *Meta-Analysis as 'The analysis of the data for a research question where are plural trials*.' " ([33], p. 1418)

In short, the essential procedure of the meta-analysis, summarized by K. Tsutani as follows, suggests that our analysis of the data in the CFP in the last 30 years should be classified as this method even if it may have not done completely as the work of an individual:

"The Process of the Meta-Analysis ([34], pp. 1417–1418), Translated into English by H.K.)

There are seven steps in a meta-analysis:

(1) *Set the Research Theme, i.e. the Research Question.*
    In the first step "Identification of the Problem" of the EBM, the four elements called "PECO" (i.e. patient, exposure, comparison, and outcome) are about a specific patient. In the identification of the problem at the meta-analysis, the generalized "name of disease" corresponds to the patient in the PECO.
(2) *Collection of Research without Exception.*
    This is a very important step. We have to collect as many trials as possible including unpublished ones to avoid publication bias. Considering this point, it is very difficult to develop the systematic review at the individual level. It is desirable to have support by public organizations.
(3) Evaluation of Values of Individual Researches
(4) Summarization of the Result of the Evaluation
(5) Systematic Analysis of the Result
(6) Interpretation of the Result
(7) Edit and Publication of the Result periodically"

5. Conclusion

Nuclear reactions in the CFP, including nuclear transmutation, are wonderful phenomena difficult to understand with traditional solid-state physics and nuclear physics. The confusion in this field since the discovery of the cold fusion phenomenon in 1989 has shown the overwhelming influence of the deductive logic established in modern science since 17th century as seen in the history of the CFP [36].

To understand the complex experimental data obtained in the CFP consistently, we have to depend on the phenomenological approach with a model [4,5] as a kind of meta-analysis and then on the quantum mechanics to investigate the premises used in the model [7]. The model proposed in 1994 (TNCF model) successfully explained various events observed in the CFP. The consistent explanation of experimental facts by the model has shown the reality of the participation of neutrons in the nuclear reactions in the CF materials where the CFP has been observed. The quantum mechanical investigation of the nuclear interaction between lattice nuclei and interstitial protons or deuterons has given a new feature of the interaction between lattice nuclei in the CF materials [7].

It is valuable to point out the use of the meta-analysis in such complex situations as those met in the medical fields, where they call the analysis "EBM" (evidence based medicine) or "Systematic Review." The analysis of the data sets

in the CFP performed in our works [5,7] could be classified as a kind of the meta-analysis. In forthcoming papers [31,35], we will give an extensive investigation of the meta-analysis in the CF research. We also notice that the logic used in our explanation of the CFP by the TNCF model is classified into the inductive logic rather than the deductive one prevalently used in the modern science developed after 17th century. We will discuss these points extensively in these forthcoming papers.

We have explained several characteristics of the nuclear transmutations and the decay-time shortenings obtained in non-biological CF materials as follows:

(1) In electrolytic systems, the electrolyte elements (Li, K, and so on) adsorbed on the cathodes (Pd, Ni, and so on) have shown nuclear transmutations at the near surface layers to a depth of a few micrometers ([5], Section 11.11, [7], Section 2.5.1).
(2) In the case of actinoid hydrides and deuterides, co-deposited U_3O_8 and H on Ni cathode has shown the decay-time shortening of uranium [17].

In addition to these examples obtained in non-biological CF materials, there are nuclear transmutations and decay-time shortenings in biological systems as introduced in Section 3.

We must recognize the importance of the problem of how to treat nuclear waste that is piling up in our society. The patent issued recently for the "Method of Treatment of the Radioactive Waste" (in Japanese) [20] shows the urgency of such treatment.

We have given a consistent explanation for the nuclear reactions in various CF materials from the biotransmutation, i.e. nuclear transmutation in biological systems, to nuclear transmutations in other CF materials. If our explanation of the biotransmutation is correct, we can contemplate the application of this phenomenon to nuclear waste treatment as follows.

As the patent [20] shows clearly, the method based on the nuclear physics in free space is a rival to the treatment of radioactive waste by the CFP. The key factor in this competition is the cost-performance ratios of two methods. We have to check our technique in detail as soon as possible.

As we know from experimental results presented briefly in this paper, the nuclear reactions in the CFP occur at localized regions near boundaries of CF materials and the efficiency of the nuclear reactions is exceptionally higher than that occurs in free space. On the other hand, we need CF materials that have longevity. We may have many factors to check before realization of these new techniques. Anyway, competition is always desirable to improve techniques.

It is well known that some biological systems characteristically adsorb specific anion or cation selectively. These characteristics of the biological systems may enable us to use them effectively to remediate hazardous nuclear waste.

We can systematize the process of biotransmutation research as follows: First, find microorganisms that adsorb ions of specific elements. Second, find microorganisms that affect unstable nuclear states adsorbed on the surface. Third, determine the molecular structures of the microorganism that has shown the ability of nuclear transmutation. Using these three steps cyclically, we can make progress in the research of remediation of hazardous nuclear wastes by the biotransmutation.

It may be possible to imagine a fantastic dream to have some microorganisms that obtain their energy from unstable nuclei destabilizing them by the mechanism we had known in the biotransmutation summarized in this paper. Biological systems are a source of miracles we have had in past and will have in future.

Acknowledgement

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Extended Abstract

Thermodynamic Prediction for Novel Environmental Biotechnologies of Radioactive Waste Water Purification

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Abstract

Extended Abstract is given.

Keywords: Bioremediation of ecosystems, Biotechnologies, Microorganisms, Purification of radioactive waste water, Thermodynamic prediction

Extended Abstract

The universal concept of thermodynamic justification of novel biotechnologies to purify liquid radioactive waste and for bioremediation of polluted ecosystems from a wide range of radionuclides and toxic metals has been developed. The main provisions of the concept are based on the thermodynamic prediction of the interaction of microorganisms, algae and vascular plants with radionuclides and metals of the periodic system of elements.

They are the following.

(1) Thermodynamic prediction of microorganisms and plants interaction with metals and radionuclides.
   (a) Nonspecific reduction of metals and radionuclides to insoluble compounds.
   (b) Metals and radionuclides accumulation due to their stereochemical analogy with macroelements.
   (c) Integration of interaction mechanisms: nonspecific reduction and nonspecific accumulation.

(2) Application of thermodynamic prediction and concentration functions of I and II order (by V. Vernadskii) is used to estimate the theoretically permissible and effective integrated mechanisms of radionuclides accumulation.

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(3) Development of a theoretical basis of comprehensive biotechnologies for the purification of radioactive waste water and for bioremediation of ecosystems.

The nonspecific reduction of radionuclides to insoluble compounds is based on redox properties of binary systems consisting of metabolically active microorganisms and radionuclides. Microorganisms serve as the donor system and radionuclides are the acceptor system. If a potential difference between these systems is 100 mV and higher, microorganisms inevitably reduce soluble oxidized radionuclide compounds to insoluble ones:

$$^{51}\mathrm{CrO}_4^{2-} + 3\mathrm{e} + (n-1)\,\mathrm{H_2O} + 5\mathrm{H}^+ = {}^{51}\mathrm{Cr(OH)}_3\, n\mathrm{H_2O}\downarrow,$$

$$^{51}\mathrm{Cr(VI)\ soluble} + 3\mathrm{e} = {}^{51}\mathrm{Cr(III)\ insoluble},$$

$$4[\mathrm{UO_2(CO_3)_3}]_4^- + \mathrm{HS}^- + 15\,\mathrm{H}^+ = 4\,\mathrm{UO_2} + \mathrm{SO}_4^{2-} + 12\,\mathrm{CO_2} + 8\,\mathrm{H_2O},$$

$$^{238}\mathrm{U(VI)\ soluble} + 2\mathrm{e} = {}^{238}\mathrm{U(IV)\ insoluble}.$$

To implement this kind of method to remove of radionuclides from solutions, the standard redox potential of the reduction of radionuclides must be within the zone of thermodynamic stability of water (–414 < Eh < +814 mV). For example, ^{51}Cr(III) can not be reduced to metallic chromium, since the standard potential of its reduction reaction is more electronegative than the potential of the lower limit of water stability ($E_0' = -414$ mV):

$$^{51}\mathrm{Cr(OH)}_3\,3\mathrm{H}^+ + 3\mathrm{e} = {}^{51}\mathrm{Cr}^0 + \mathrm{H_2O}, \quad E_0' = -1000\ \mathrm{mV}.$$

Radionuclides, for microbial reduction of which a thermodynamic inhibition takes place, will be accumulated by microorganisms due to their stereochemical analogy with macroelements. The macroelements include the ions necessary for the metabolism of microorganisms: K^+, Na^+, Ca^{2+}, Mg^{2+}, SO_4^{2-}, PO_4^{3-}, etc. Stereochemical analogy is the proximity or equality of ionic radii of macroelements and radionuclides. For example, $^{90}\mathrm{Sr}^{2+}$ is the stereochemical analogue of Ca^{2+}, for which the ionic radius (IR) is 0.11 nm. The ions of $^{83}\mathrm{Rb}^+$ (IR = 0.15 nm), $^{226}\mathrm{Ra}^{2+}$(IR = 0.155 nm) and $^{134,137}\mathrm{Cs}^+$(IR = 0.165 nm) are the stereochemical analogs of NH_4^+ (IR = 0.15 nm). That is why the acceptor transport systems of microorganisms intended for the absorption of macroelements are wrong and transport radionuclides together with macroelements inside cells.

The integration of two mechanisms for removal of radionuclides from aqueous solutions (reduction to insoluble compounds and accumulation due to a stereochemical analogy) provides effective purification of liquid radioactive waste.

The effectiveness of accumulation of radionuclides by living organisms (microorganisms, microalgae, algae, vascular plants, etc.) is determined by V. Vernadskii's equation for Biogeochemical Energy of Growth and Proliferation:

$$2^{n\Delta} + (\alpha+1)^n = Nn.$$

In this equation *n* is number of days, 2 the initial number of organisms, *N* is the number of organisms after *n* days growth, α the daily increase in number of organisms (cells), and Δ the coefficient of proliferation (generations per day).

The effectiveness of radionuclide accumulation is determined primarily by the value of the index α, that is, effectiveness of growth and proliferation. For microorganisms (*Escherichia coli*) $\alpha = 2.78\times10^{18}$, for unicellular organisms

(*Infusoria* and *Diatomea*) $\alpha = 2.32$, and for vascular plants (*Solanum nigrum*) $\alpha = 0.03$. Obviously, microorganisms should be used in biotechnologies for the dominant extraction of radionuclides from solutions. The role of other organisms (microalgae, algae, vascular plants, etc.) lies in the deep post-treatment of liquid radioactive waste; that is to say, the extraction of radionuclides in vanishingly small concentrations.

It follows that artificial ecosystems consistently consisting of the three following blocks are the most promising for the effective purification of liquid radioactive waste.

(1) The biomass of microorganisms in artificial marshes (effectiveness of radionuclide removal – 95%).
(2) Ponds with water plants (effectiveness of radionuclide removal – 4%).
(3) Filter fields with soil plants (effectiveness of radionuclide removal – 0.999%).

Hence it is obvious that the method of thermodynamic prediction of the interaction of microorganisms and other living organisms with radionuclides makes it possible to theoretically substantiate and provide the development of novel biotechnologies for the purification of liquid radioactive waste from a wide range of radionuclides.

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Extended Abstract

Novel Biotechnologies for Purification of Radioactive Waste Water

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Abstract

Extended Abstract is given.

Keywords: Effective biotechnologies, Extraction of radionuclides, Microbial pellets, Thermodynamic prediction

Extended Abstract

Based on our concept of thermodynamic prediction of microbial interaction with radionuclides and toxic metals, we developed novel environmental biotechnologies based on microbial pellets. The main properties of the pellets are the following:

- high stability of pellets (due to their structure) in water solutions,
- diversified microbial communities (natural and artificial),
- compounds necessary for active microbial metabolism,
- presence of Regulators of Microbial Metabolism (RMM),
- high concentration of living microorganisms (95–98% weight of pellets).

Due to these properties, the microbial communities of pellets carry out many types of interaction with radionuclides. The interactions are divided into three groups. The first group is outside the cell, the second is on the cell membrane of microorganisms, and the third is inside the cell. When radionuclides are added into a metabolically active culture radionuclides-oxidizers are reduced by microbial exometabolites-reducers to insoluble compounds ($^{51}CrO_4^{2-}$ to insoluble $^{51}Cr(OH)_3\ nH_2O\downarrow$ or $^{238}UO_2OH^+$ to insoluble $^{238}UO_2\downarrow$). Simultaneously the precipitation of radionuclides with exometabolites takes place, e.g.

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Table 1. Efficiency of extraction of radionuclides by microbial pellets from liquid radioactive waste (LRW).

Radionuclide	Activity** of radionuclides (Ki/kg)			The order of LRW activity decrease
	Initial in LRW	In Microbial Pellets	In LRW after purification	
^{51}Cr	3.90×10^{-7}	1.18×10^{-7}	*	5
^{54}Mn	6.70×10^{-8}	4.72×10^{-8}	*	4
^{60}Co	1.09×10^{-6}	5.3×10^{-6}	5.36×10^{-11}	5
^{83}Rb	6.22×10^{-7}	4.16×10^{-7}	*	5
^{90}Sr	3.52×10^{-7}	3.39×10^{-7}	*	5
^{137}Cs	1.36×10^{-5}	7.81×10^{-5}	3.36×10^{-9}	4
^{140}La	7.01×10^{-8}	9.67×10^{-8}	*	4
^{144}Ce	6.17×10^{-6}	3.50×10^{-6}	7.22×10^{-9}	3
^{226}Ra	1.21×10^{-6}	1.11×10^{-6}	7.60×10^{-8}	2

*Indicates less than sensibility of spectrometer (1.0×10^{-12} Ki/kg).
** Radioactive wastewater of the Institute for Nuclear Research (the National Academy of Sciences of Ukraine) measured by Valeriy Shevel.

$$^{194}\mathrm{Hg}^{2+} + \mathrm{CO}_3^{2-} = ^{194}\mathrm{HgCO}_3^{2-} \downarrow \quad \text{and} \quad ^{60}\mathrm{Co}^{2+} + \mathrm{S}^{2-} \rightarrow ^{60}\mathrm{Co}S \downarrow .$$

It is also possible to bind radionuclides with exopolysaccharides, which are excreted by cells into the external space. Furthermore, the following process occurs on the external cellular structures. Radionuclides substitute stereochemical analogues in the cell wall. Thus, $^{90}Sr^{2+}$ and Ca^{2+} have equal ionic radii (IR), 0.11 nm. Similarly, ionic radii of $^{239}Pu^{6+}$ and Mg^{2+} are equal 0.075 nm that is why $^{239}Pu^{6+}$ substitutes Mg^{2+} in the cell wall. Additional radionuclides are actively transported into cells also due to stereochemical analogy of radionuclides and macroelements. The acceptor and transport systems of microorganisms are activated to transfer radionuclides together with macroelements inside cells. For example, since $^{51}CrO_4^{2-}$ and SO_4^{2-} has equal ionic radii 0.300 nm radioactive chromium is actively transported in cells. Ions of $^{90}Sr^{2+}$ are transported in the same way, since they have the same ionic radii with

Table 2. Types of interaction of microorganisms with radionuclides.

Radionuclide	Type of interaction
$^{51}CrO_4^{2-}$	– Transport inside cells (stereochemical analogue of SO_4^{2-})
	– Reduction to insoluble Cr(III) outside and inside cells
$^{137}Cs+$	– Transport inside cells (stereochemical analogs of K^+ and NH_4^+)
$^{83}Rb^+$, $^{226}Ra^{2+}$	– Incorporation in cell compounds (substitution of NH_2-groups in amino acids)
$^{90}Sr^{2+}$	– Transport inside cells (stereochemical analogue of Ca^{2+})
	– Precipitation by exometabolites in insoluble compounds:
	– $Sr^{2+} + CO_2 \rightarrow SrCO_3 \downarrow$ (solubility index, SI $= 1.1\times 10^{-10}$)
	– $Sr^{2+} + H_2S \rightarrow SrS + 2H^+ + S^o \rightarrow Sr(OH)_2 \downarrow$
$^{54}Mn^{2+}$	– Transport inside cells (stereochemical analogs of Mg^{2+})
$^{60}Co^{2+}$	– Precipitation by exometabolites in insoluble compounds:
	– $Mn^{2+} + Co^{2+} + CO_2 \rightarrow MnCO_3 + CoCO_3 \downarrow$(SI $= 1.1\times 10^{-10}$)
	– $Mn^{2+} + Co^{2+} + 2H_2S \rightarrow MnS\downarrow + CoS\downarrow + 2H^+$ (SI $= 1.0\times 10^{-13}$)
$^{140}La^{3+}$	– Transport inside cells (stereochemical analogue of Ca^{2+})
$^{144}Ce^{3+}$	– Precipitation by exometabolites in insoluble compounds:
	– $Ce^{3+} + H_2S \rightarrow Ce_2S_3 \downarrow + 2H^+ + S^o$
	– $La^{3+} + H_2S \rightarrow La_2S_3 \downarrow + H_2O = La(OH)_3 \downarrow$

Ca^{2+}. After transfer into cells, radionuclides-oxidizers are reduced by redox enzymes to insoluble compounds, and also precipitated by metabolites.

We were able to effectively extract radionuclides using microbial pellets, from liquid radioactive waste obtained from the Institute for Nuclear Research of the National Academy of Sciences of Ukraine. The efficiency of extraction of radionuclides was high. Within three days, the activity of the solution decreased on average by 4–5 orders due to the accumulation of radionuclides in microbial pellets (Table 1).

Based on the thermodynamic predictive method, it is possible to explain the high efficiency of radionuclides extraction by microorganisms as follows (Table 2).

Thus, we have shown the possibility of using the thermodynamic predictive method to develop effective, novel biotechnologies for purification of liquid radioactive waste from a wide range of radionuclides. Obviously, the method developed by us will be effective for biotechnologies for purification of any types of liquid radioactive waste.