# Accelerated deactivation of water solutions of reactor radionuclides by transmutation to stable isotopes in growing microcultures
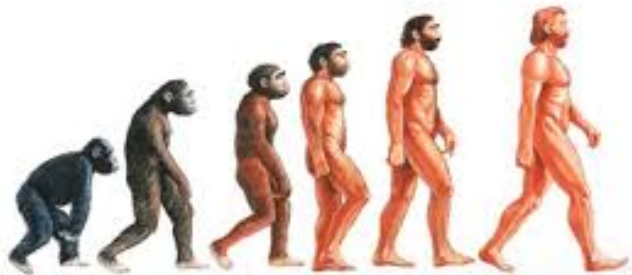## (prehistory, experiments, theory, perspectives)

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Biota

Nuclear world

???

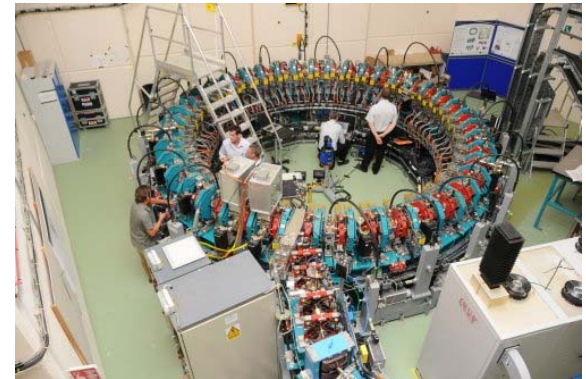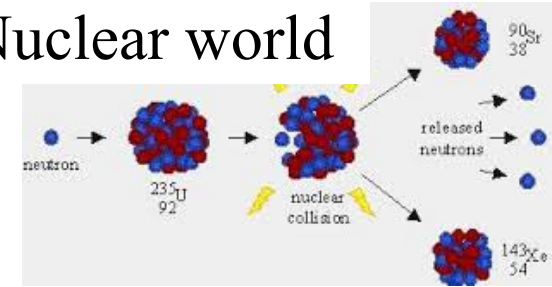**Two worlds and a possible bridge between them**
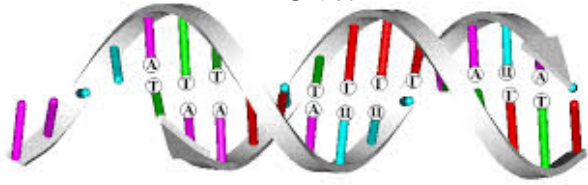
Представители хордовых животных: 1 — костная рыба (сазан); 2 — земноводное (озерная лягушка); 3, 4 — пресмыкающиеся (прыткая ящерица, кобра); 5 — птица (сойка); 6 — млекопитающее (волк)

Contents

The report presents the results of combined examinations of stable and radioactive isotope nuclear transmutation in water by growing microbiological cultures.

Prehistory

The hypothesis about the possibility of nuclear transmutation of chemical elements and their isotopes in biological systems is one of most mysterious in the natural history and has been frequently discussed during the last decades.

The problems of transmutation and synthesis of chemical elements during the "pre-nuclear period" have their own history and mythology, own proponents and critics.

The series of works *Prof. C. Louis Kervran* (Paris Univ.) (1901-1983) holds a special place in the chronology of transmutation of chemical elements and isotopes in biological objects:

Kervran C. L. Transmutations Biologiques, Métabolismes Aberrants de l'Azote, le Potassium et le Magnésium, Librairie Maloine S.A., Paris, 1963;
Kervran C. L. *A la Découverte des Transmutations Biologiques, Librairie Maloine* S.A., Paris, 1966;
Kervran C. L. Preuves Relatives à l'Existence de Transmutations Biologiques, Librairie Maloine S.A., Paris, 1968;
Kervran C. L. Biological Transmutations, Happiness Press, USA, Magalia, California,1998;

Effectively, Louis Kervran was the first scientist of the post-nuclear era, who conducted systematized research of possible transmutational processes of chemical elements in biological objects.
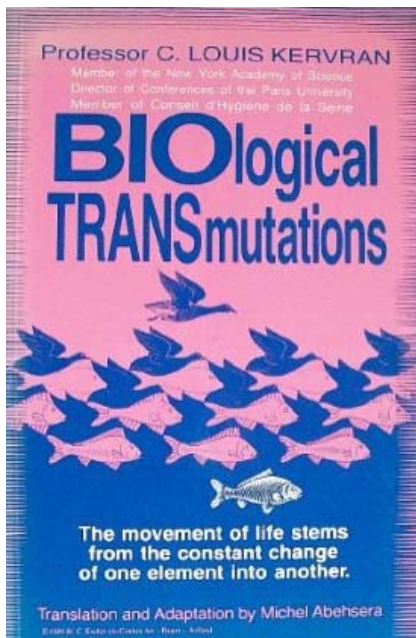
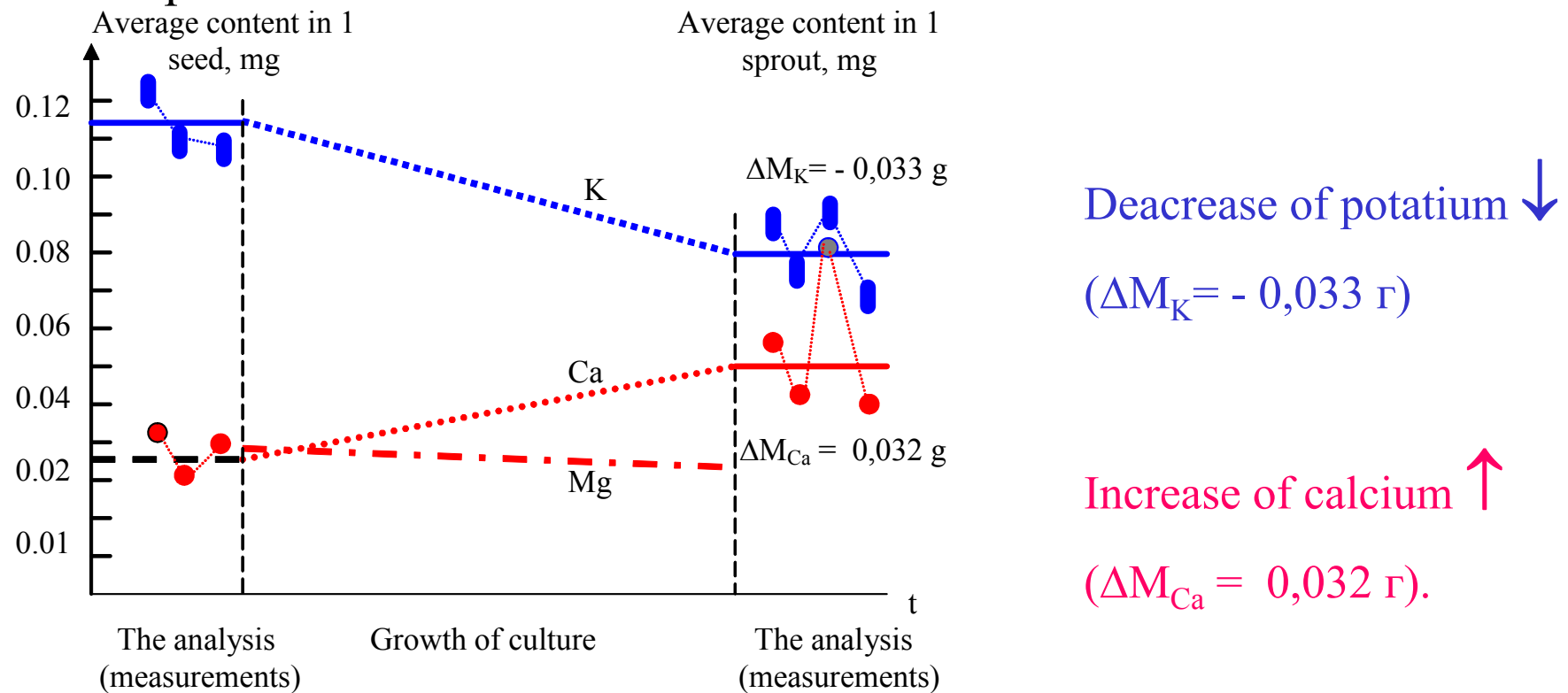**Kervran** has investigated the reaction $K^{39} + p^1 = Ca^{40}$ of potassium transmutation into calcium in the biological system containing hydrogen. This data corresponds to changes in potassium and calcium content in the process of growing seeds and were obtained from the analysis of 840 seeds and 403 sprouts.

Changes in K and Ca content in the seeds and sprouts. The left and the right parts of the figure show the measurement results by three series and average results

Kervran also investigated many other reactions of transmutation of isotopes, among which several should be specifically noted for their vital activity in producing essential elements *Ca, K, Mg, P*

$$Na^{23} + p^1 = Mg^{24}, \ Mg^{25} + Li^6 = P^{31}, Na^{23} + O^{16} = K^{39},$$

$$Mg^{24} + O^{16} = Ca^{40}, \ Si^{28} + C^{12} = Ca^{40}$$
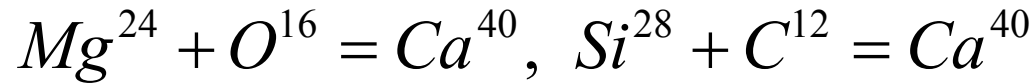
As a proof of running the reaction

$$Na^{23} + O^{16} = K^{39}$$
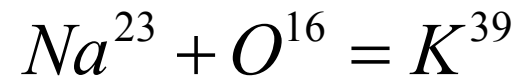
Kervran provided the experimental data (Jullien, 1959). According to this data, placing a tench fish into water, containing 1.4% of sodium chloride NaCl for 4 hours lead to 66% increase in KCl concentration in the blood of a tench fish for the same period of time.
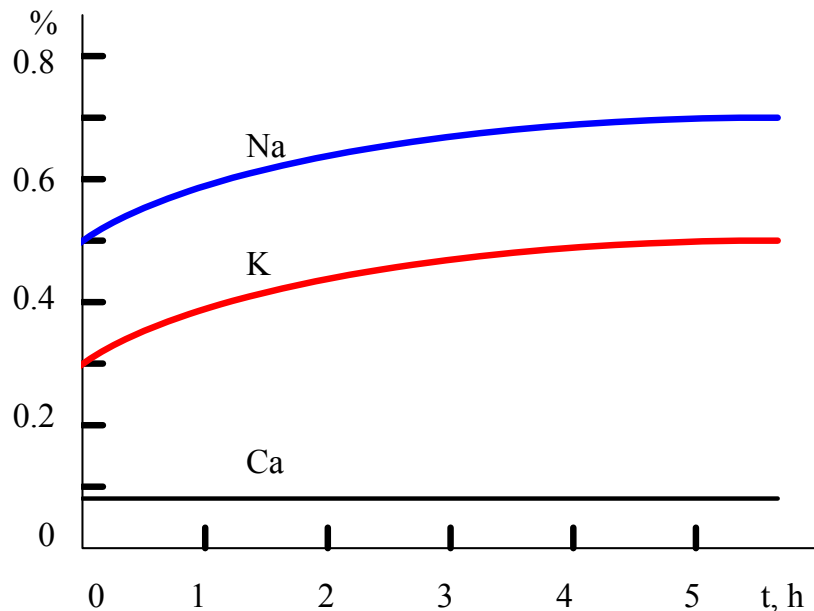
Changes in content of Na, K and Ca in the blood of a tench fish, immersed in water containing 1.4% of NaCl.

From the other hand the Kervran's point of view was far from standard nuclear conceptions.

1. **He considered the reaction**

$$_7N^{14} + {}_7N^{14} \rightarrow {}_6C^{12} + {}_0n^1 + {}_1p^1 + {}_7N^{14} \rightarrow {}_6C^{12} + {}_8O^{16}$$
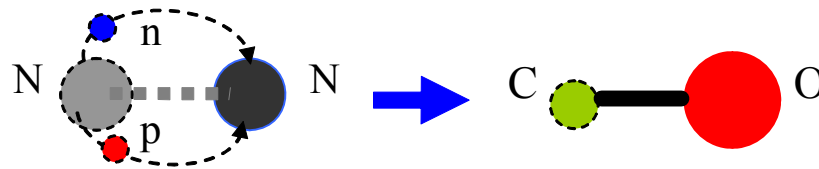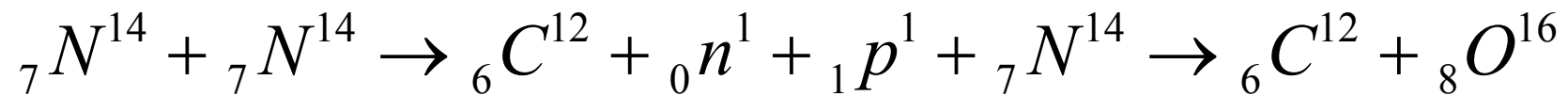
as the process of proton and neutron space transition in the N$_2$ molecule from one nucleus of nitrogen to another (with transformation of one nucleus of nitrogen into carbon and another — into oxygen). He suggested that this process will take place in a biological system at action of unknown enzyme in conditions of carbon deficit.

There are no reasons for such hypothesis!

2. He often used concept of the reversibility of threshold transmutation process at which the law of conservation of energy is broken.

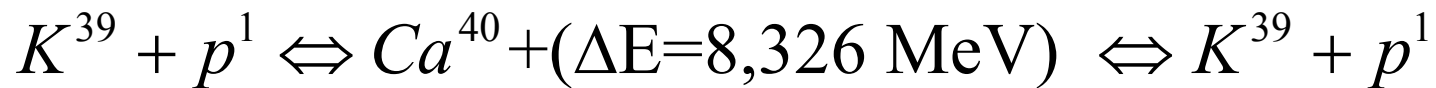For example, he postulated the possibility of inpossible reversing the reaction of potassium transmutation into calcium

$$K^{39} + p^1 \Leftrightarrow Ca^{40} + (\Delta E = 8,326 \text{ MeV}) \Leftrightarrow K^{39} + p^1$$

Such examples of careless assumptions are numerous in Kervran's works.

For instance, reactions of direct fission of isotopes, analyzed by him,

$$Cl - O \rightarrow F, \ P - Li \rightarrow Mg, \ Ca - O \rightarrow Mg, \ Fe - H \rightarrow Mn,$$

which, according to his opinion, can be sustained in living systems, are exoenergetic and need a huge amount of additional energy, equal to 5–20 MeV for a single reaction.

3. Kervran has not analyzed isotope ratio in initial and final states in any of his experimental works. It is the main mistake of Kervran's experiments because **"nuclear physics is science of isotopes (not elements!) transmutation"**

4. In all own works Kervran has called the process of transformation of elements in biological systems as special *"biological transmutation"*.

In our opinion, there are no reasons to consider the process of transformation of isotopes in growing biological systems as "biological transmutation" and separate it from the general physical concept of transmutation as a process of transformation of isotopes in special dynamical environmental , governed by the laws of physics.

Experiments on controlled transmutation of nuclear isotopes in growing microbiological cultures

Experimental investigation of fusion of iron-region stable isotopes in "one-line" growing microbiological cultures

About 25 years ago we have studied and reported the process of transmutation of stable isotopes in growing "one-line" microbiological cultures in nuclear reaction

$$Mn^{55} + d^2 = Fe^{57} + 15.6\,MeV; \quad \eta_{Fe^{54}} \approx 5.8\%, \, \eta_{Fe^{56}} \approx 91.8\%, \, \eta_{Fe^{57}} \approx 2.2\%$$
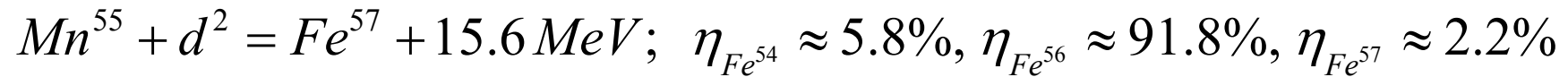
The researches were carried out on different bacterial cultures.
Cultures were placed in a flask with sugar-salt nutrient medium

Components	Concentration in medium (%)	Admixture of Fe (no more) relative (%)	Admixture of Fe (no more) absolute (g)
Sucrose	3	10^{-4}	3.10^{-7}
$(NH_4)_2$ tartrate	1	5.10^{-4}	5.10^{-7}
$MgSO_4 \cdot 7H_2O$	0,25	2.10^{-4}	5.10^{-8}
$CaHPO_4 \cdot 7H_2O$	0,008	$1,5.10^{-3}$	$1,2.10^{-8}$
K_3PO_4	0,5	5.10^{-4}	$2,5.10^{-7}$
$MnSO_4 \cdot 7H_2O$	0,01	5.10^{-4}	5.10^{-9}
Pure water (D_2O or H_2O)	100 (10 ml)	10^{-7}	10^{-8}

A typical series of experiments concerning nuclear transmutation of elements consisted in growing of microbiological culture in 3 disks simultaneously (see Fig.1)

$$Mn^{55} + d^2 = Fe^{57}$$

Culture

$$Mn^{55} + p^1 = Fe^{56}$$

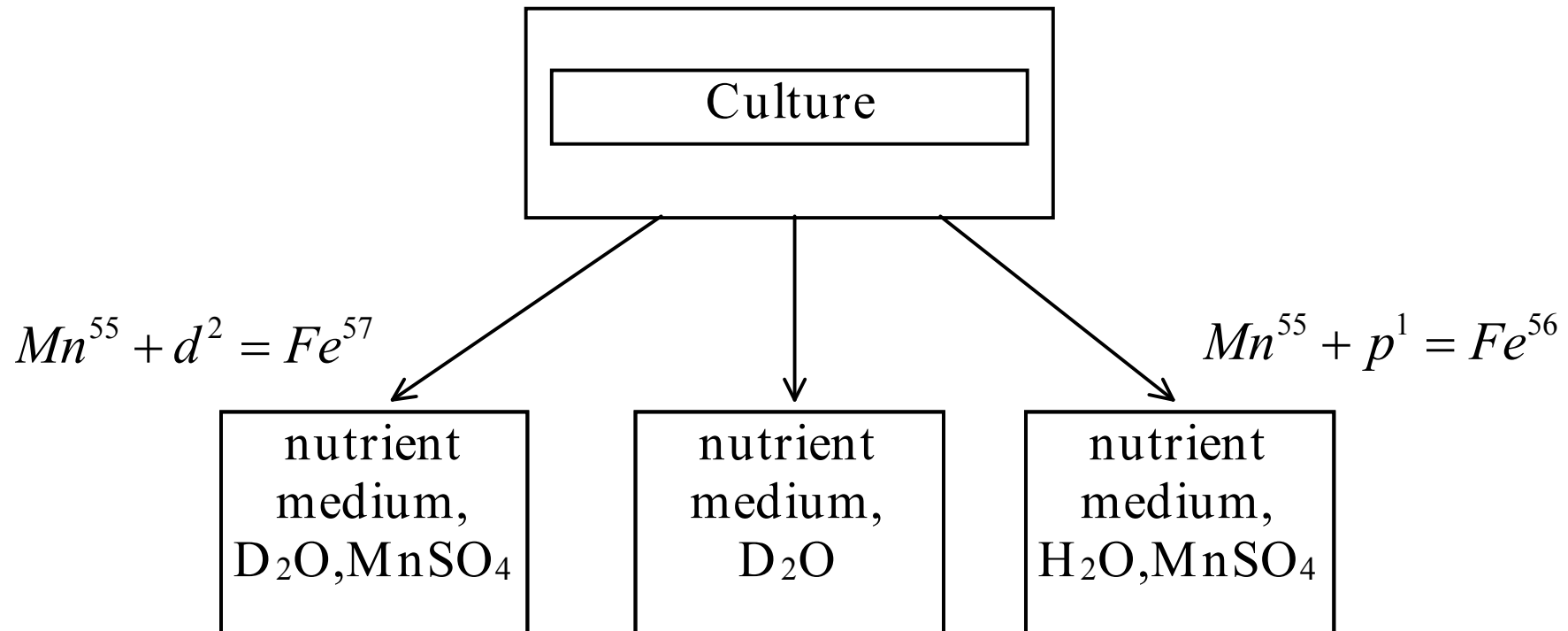| nutrient medium, $D_2O, MnSO_4$	nutrient medium, D_2O	nutrient medium, $H_2O, MnSO_4$

Fig.1 The scheme of experiment.

Such series of experiments was held for different cultures, different time of growth Δt (24, 48 and 72 hours) and different growth modes (in still disks and media and in suspension stirring mode using magnet stirring device).
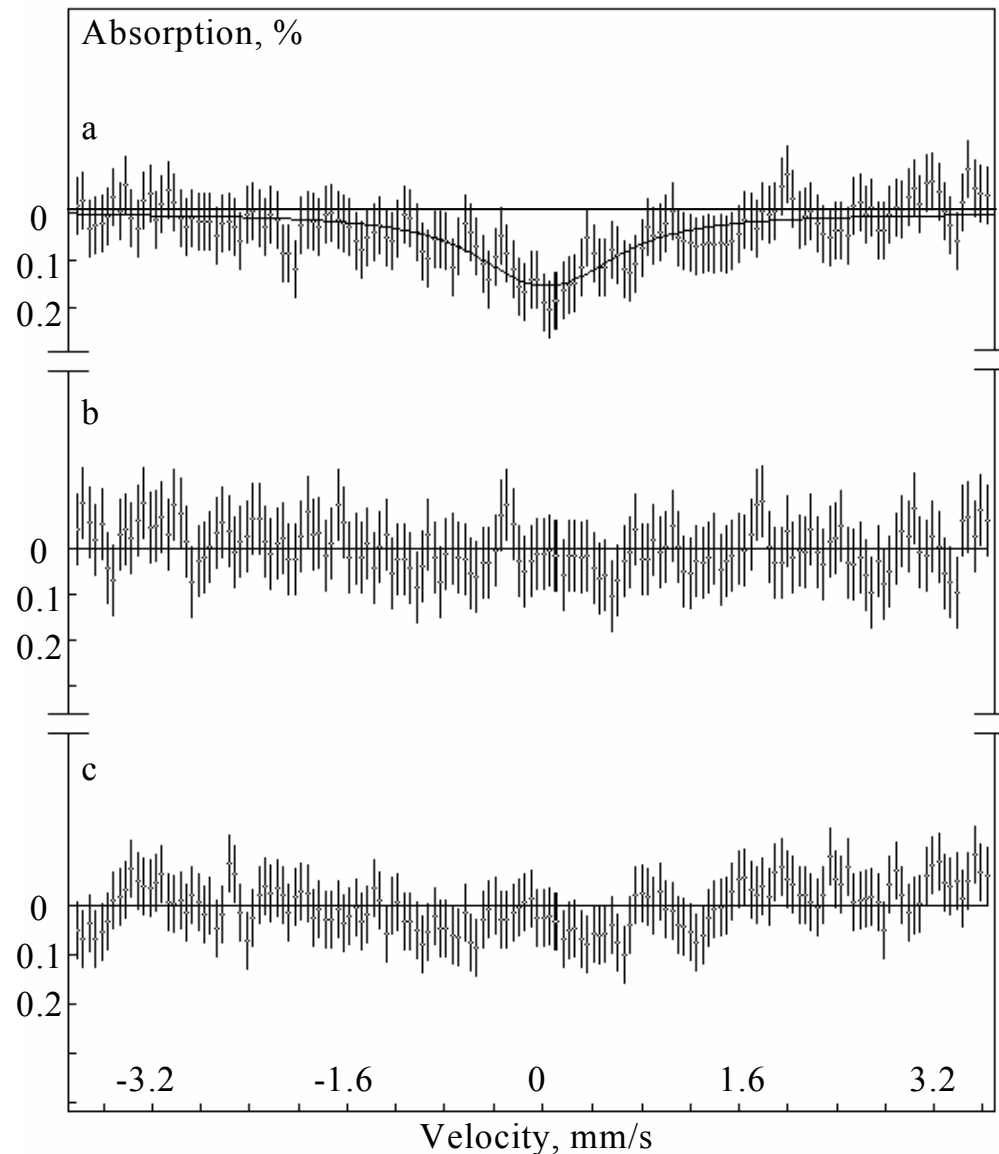
Bacteria and yeast were grown in a thermostat at optimal temperature 32 C.

Mossbauer investigation of isotope transmutation

It was shown that the transmutation process during the growth of such microbiological cultures had taken place, but its effectiveness had been low:
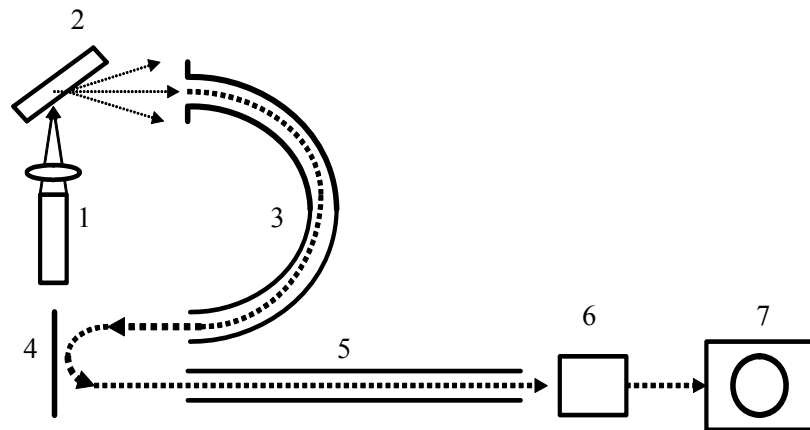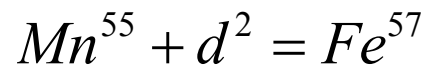
$$\lambda = \frac{\Delta N(Fe^{57})}{N(Mn^{55})\Delta t} \approx 10^{-8}$$

synthesized Fe^{57} nuclei per s and per single Mn^{55} isotope

The Mossbauer specter for the grown culture *Saccharomyces cerevisiae T-8:*
a) in D_2O with Mn^{55}; *b*) in H_2O with Mn^{55}; *c*) in D_2O without Mn^{55}

Studying of a transmutation of light and intermediate isotopes in growing microbiological culture by laser time-of-flight mass spectrometer

$$Mn^{55} + d^2 = Fe^{57}$$

Laser time-of-flight mass-spectrometer

a) $N_M/10$

Fe^{54} Fe^{56} Fe^{57}

$\approx 6\%$ $\approx 92\%$ $\approx 2\%$

Nature Fe

b) $N_M/100$

Mn^{55}

Nature Mn

c) N_M

Fe^{54} Fe^{56} Fe^{57}
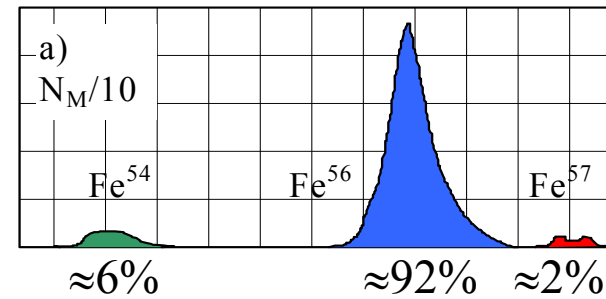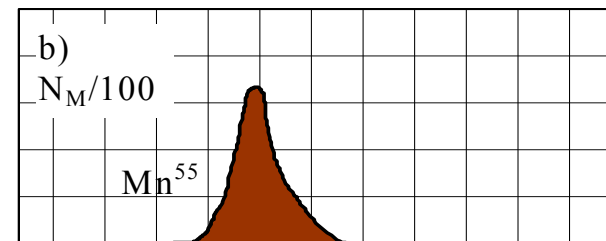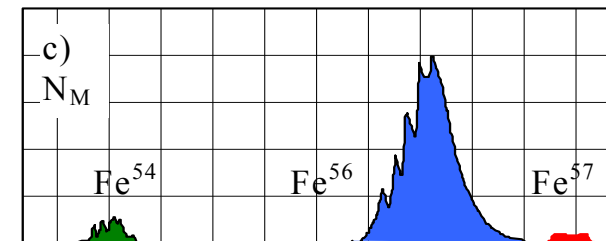
Culture grown in D$_2$O without Mn

d) N_M

Fe^{54} Fe^{56} Fe^{57}

Culture grown in D$_2$O with Mn

93   94   95   96   97   t, µs
54   55   56   57   A
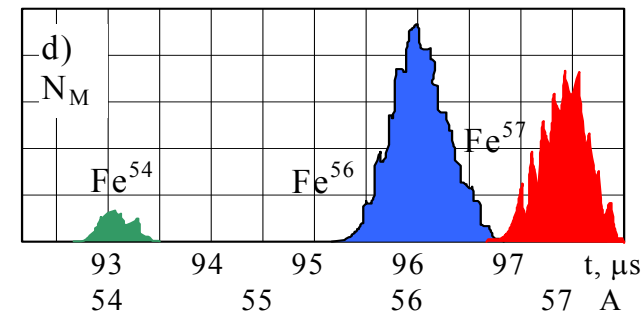
Transmutation of intermediate isotopes *(sodium, phosphorus, iron)*
in microbiological cultures was investigated in reaction $Na^{23} + P^{31} = Fe^{54}$

| Components	Concentration in medium (%)	Admixture of Fe (no more) relative (%)	Admixture of Fe (no more) absolute (g)
Sucrose	2	10^{-4}	2.10^{-4}
$MgSO_4$	0,05	2.10^{-4}	10^{-5}
$CaCO_3$	0,2	$1,5.10^{-4}$	3.10^{-5}
KCl	0,05	3.10^{-4}	$1,5.10^{-5}$
$NaNO_3$	0,5	2.10^{-4}	10^{-4}
K_2HPO_4 (experement on transmutation)	0,2	5.10^{-4}	10^{-4}
Pure water H_4O	100 (100 мл)	10^{-7}	10^{-5}

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                    Initial  microbiological culture
                        │                    │
                        ▼                    ▼
Pure natural iron   Growing in sugar-   Growing in sugar-salt
(basic experiment)  salt media without  media with K₂HPO₄
                    K₂HPO₄ (control     (experiments on
                    experiments)        transmutation)
        │                    │                    │
        ▼                    ▼                    ▼
        Combined analysis in time-of-flight laser-mass spectrometer
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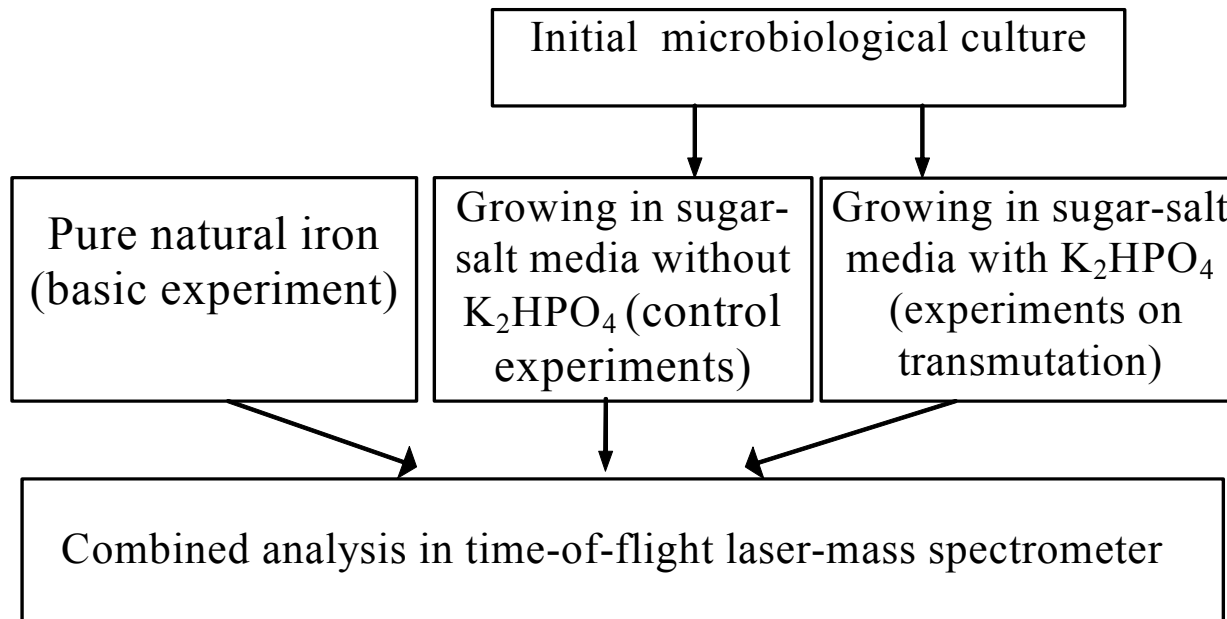
The experimental scheme on transmutation and spectrometry of isotopes with middlerange atomic numbers in microbiological culture
Escherichia coli
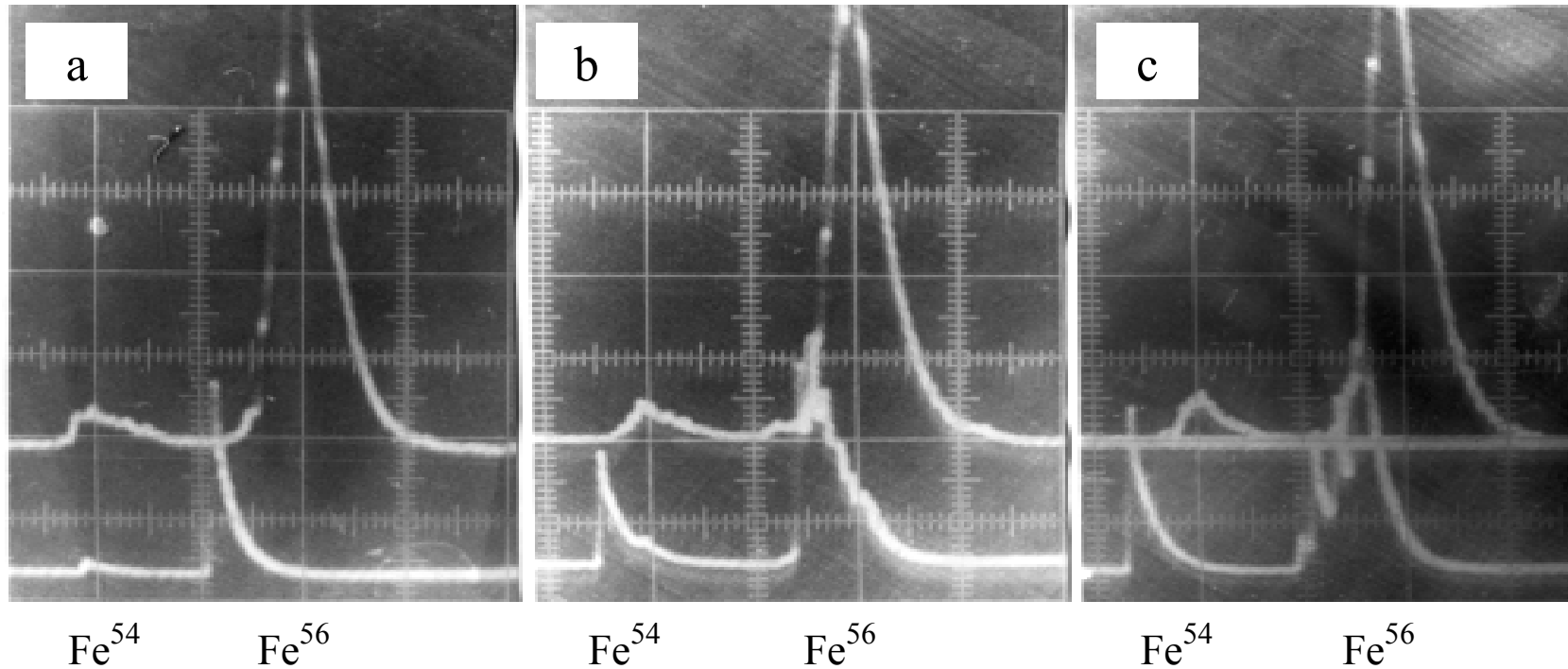
Photographs from the screen of the oscillograph with a memory, representing the mass specter in the area of isotopes of iron. **The upper graphs show the basic (benchmark) experiment for pure natural iron**; the lower graphs show the mass specter of grown microbiological culture. a) **controlling experiment (culture grown in a medium without isotope P^{31})**, b) and c) — **different transmutation experiments (culture grown in a medium in the presence of P^{31} and Na^{23}**

$$\textit{The rate of } Na^{23} + P^{31} = Fe^{54} \textit{ reaction } \lambda = \frac{\Delta N(Fe^{54})}{N(Mn^{23})\Delta t} \approx \frac{\Delta N(Fe^{54})}{N(P^{31})\Delta t} \approx 10^{-8}$$
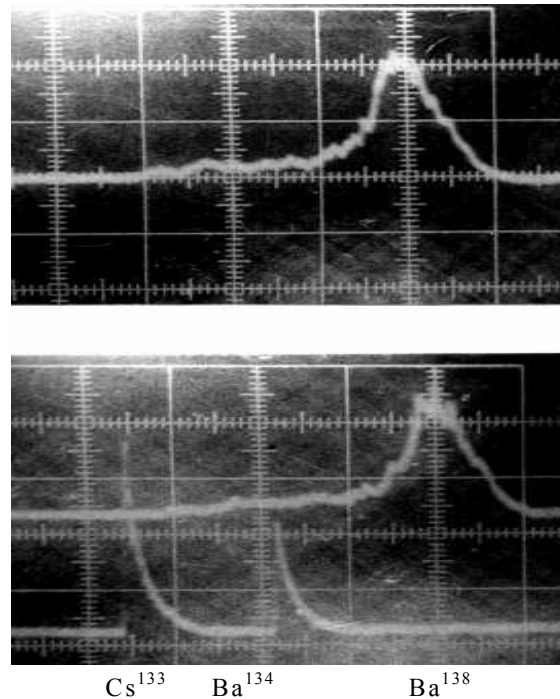
synthesized Fe^{54} nuclei per s and per single Na^{23} and P^{31} isotopes

Experiments on transmutation of intermediate and heavy isotopes $(Na^{23} + P^{31} = Fe^{54}; Cs^{133} + p^1 = Ba^{134})$

| Components of the nutrient medium	Concentration (%)
Glucose	2
$NaNO_3$	0.5
$MgSO_4$	0.05
Distilled water H_2O	100
Na_2HPO_4	0.1
Tripton	0.5
Variables components	
1. KCl	0.05
2. CsCl	0,05

Ba^{131} (*natural concentration* -0.1%),

$Ba^{134}(2.4\%)$, $Ba^{135}(0.6\%)$, $Ba^{135}(6.6\%)$,

$Ba^{136}(7.8\%)$, $Ba^{137}(11.2\%)$, $Ba^{138}(72.0\%)$

Cs^{133} Ba^{134} Ba^{138}

Mass-spectrum of natural barium (upper curves with presence of Ba^{134}, Ba^{135}, Ba^{136}, Ba^{137} isotopes and main Ba^{138} isotope (natural - 72%) and synthesized Ba^{134} isotope (natural - 2.4%) at presence of Cs^{133}

Fe^{54} Fe^{56}
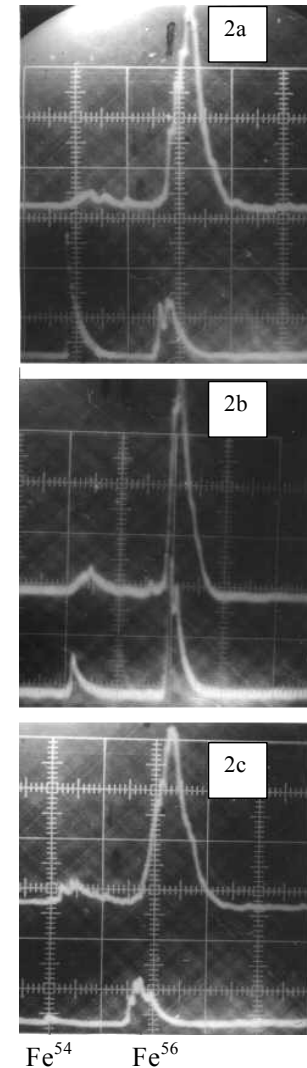
Mass-spectrums of detected Fe isotopes: upper curves - reference experiment on natural Fe; 2a - induced transmutation (in the medium with presence of Cs^{133} isotopes), 2b - spontaneous transmutation (in the medium with presence of K isotope); 2c - control experiment.

The rate of Cs^{133} transmutation $\lambda \approx 10^{-8}$ synthesized Ba^{134} nuclei per s and per single Cs^{133} isotope

There are two main reasons of low effectiveness of nuclear transmutation in "one-line" microbiological cultures:

a) The relatively low efficiency of these reactions is the result of the relative narrow interval of optimal functional individual characteristics for supporting of nuclear activity in any "one-line" type of culture. Each of the "one-line" cultures individually requires a set of specific conditions (temperature, hydrogen ion exponent pH, balanced contents of nutrient medium etc) for achieving optimal metabolic conditions during the complete period of growth. Such conditions are often absent in real experiments.

b) During the growth of a "one-line" culture, we hypothesize that processes involving forms of auto-intoxication of nutrient media by metabolic products take place.

Experimental investigation of fusion of iron-region stable isotopes in optimal growing microbiological associations

In a contrast to these "one-line" cultures, **we have investigated transmutation action of microbiological associates** that include great numbers of types of different cultures.

The base of **MCT** (microbial catalyst-transmutator) compound that was used is the microbe syntrophin associations of thousands different microorganism kinds that are in the state of complete symbiosis. These microorganisms appertain to different physiological groups that represent practically the whole variety of the microbe metabolism and relevantly all kinds of microbe accumulation mechanisms.
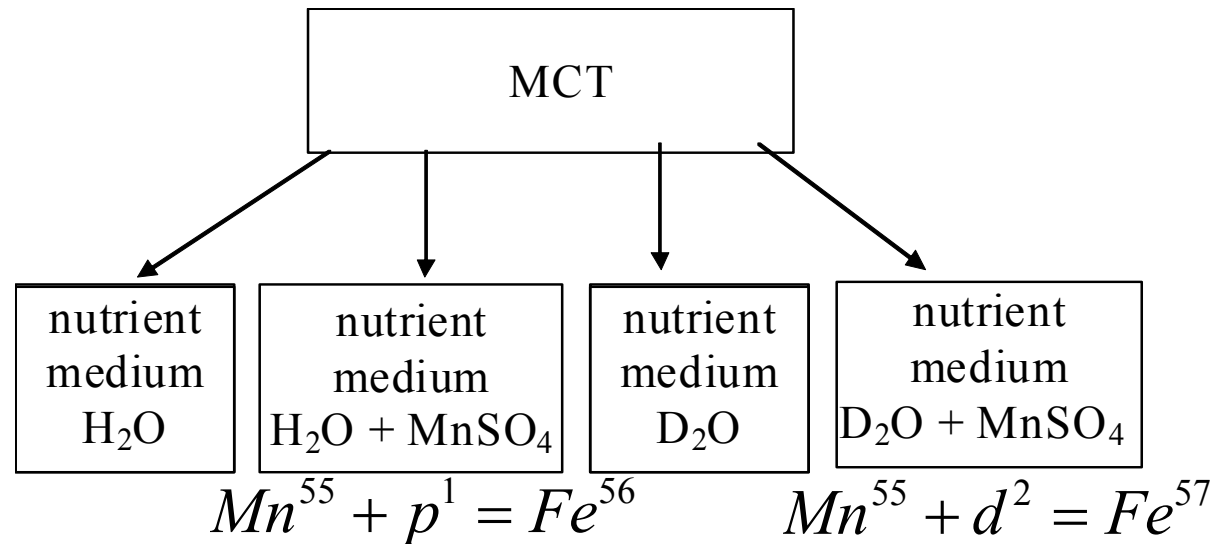
The *MCT* is the special granules that include:
1. concentrated biomass of metabolically active microorganisms (microbe syntrophin associations of thousands different microorganism kinds that are in the state of complete symbiosis);
2. sources of carbon and energy, phosphorus, nitrogen, etc.;
3. gluing substances that keep all components in the form of granules stable in water solutions for a long period of time at any external conditions.

Granules of water- stable alive cells

Investigation of nuclear reaction $Mn^{55} + d^2 = Fe^{57}$ with MCT

$$\boxed{\text{MCT}}$$

nutrient medium H_2O	nutrient medium $H_2O + MnSO_4$	nutrient medium D_2O	nutrient medium $D_2O + MnSO_4$

$$Mn^{55} + p^1 = Fe^{56} \qquad Mn^{55} + d^2 = Fe^{57}$$

Series of experiments were held for MCT during 20 days at temperature 25 C. After each series, the substance that was obtained was collected, cleaned in distilled H_2O water and dried. The dried substance in the form of unstructured granules (like peat) were separated using a non-iron containing instrument, ground to a powder and placed in the same amounts in the Mossbauer spectrometer. The mass of the dried biological substance, that was investigated, was about 0.3 g.

In this experiment the very large amplitude of the Mossbauer resonance at the same final mass of investigated dried biological substance was observed and measured.

It was the result of sharp increasing of nuclear transmutation efficiency!
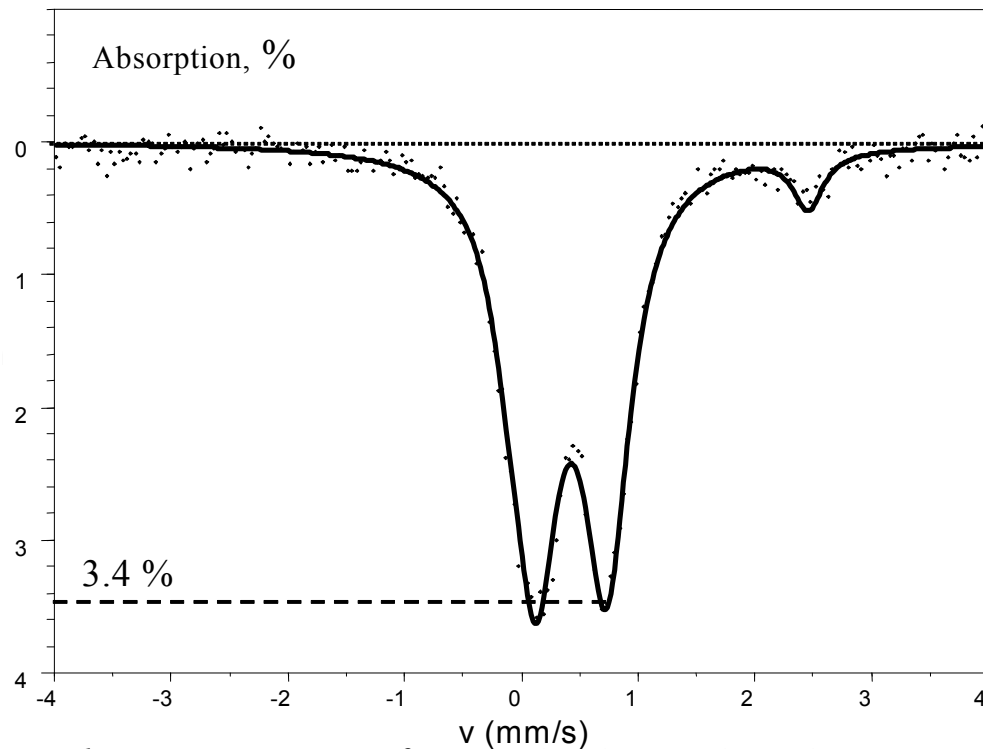
*Mossbauer spectra of **microbiological MCT** grown in the volume with presence of D_2O and Mn^{55} isotope (experiments on transmutation):*
$\Delta J_{max}/J \approx 3.4\%$ *is the magnitude of the Mossbauer resonance.*
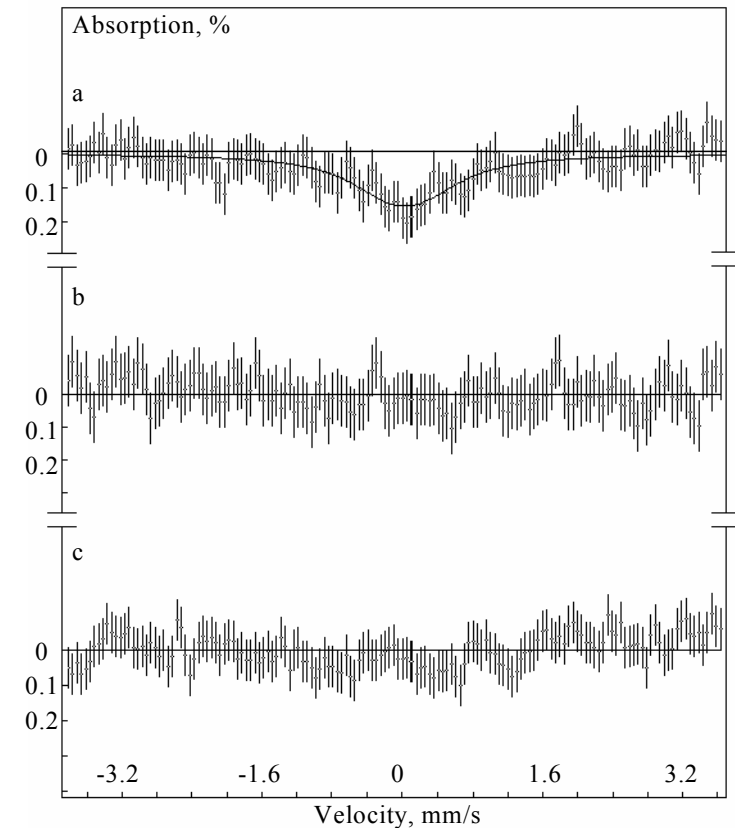
*The Mossbauer spectra for the grown culture **Saccharomyces cerevisiae** a) in D_2O with Mn; b) in H_2O with Mn55; c) in D_2O without Mn55:*
$\Delta J_{max}/J \approx 0.15\%$

The total mass of Fe-57 isotopes that was created is about 10 μg per each g of dried biological substance or by 20 times more than in the case of "one-line" culture.

The efficiency has increased, in particular, because the association has been allowed to grow during a 20 day period.
"One-line" cultures cannot be grown for such a long period of time in heavy water because of "self-intoxication" of the medium by the metabolic products (in our former experiments the "one-line" *Escherichia coli* culture was grown during a 72 hour period).
The relative efficiency rate λ of such forms of transmutation (the coefficient of transmutation) is the following:

$$\lambda = \frac{\Delta N(Fe^{57})}{N(Mn^{55})\Delta t} \approx 10^{-6} \text{ synthesized Fe}^{57} \text{ nuclei per s and per single Mn}^{55} \text{ isotope}$$

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

$$Mn^{55} + d^2 = Fe^{57}$$
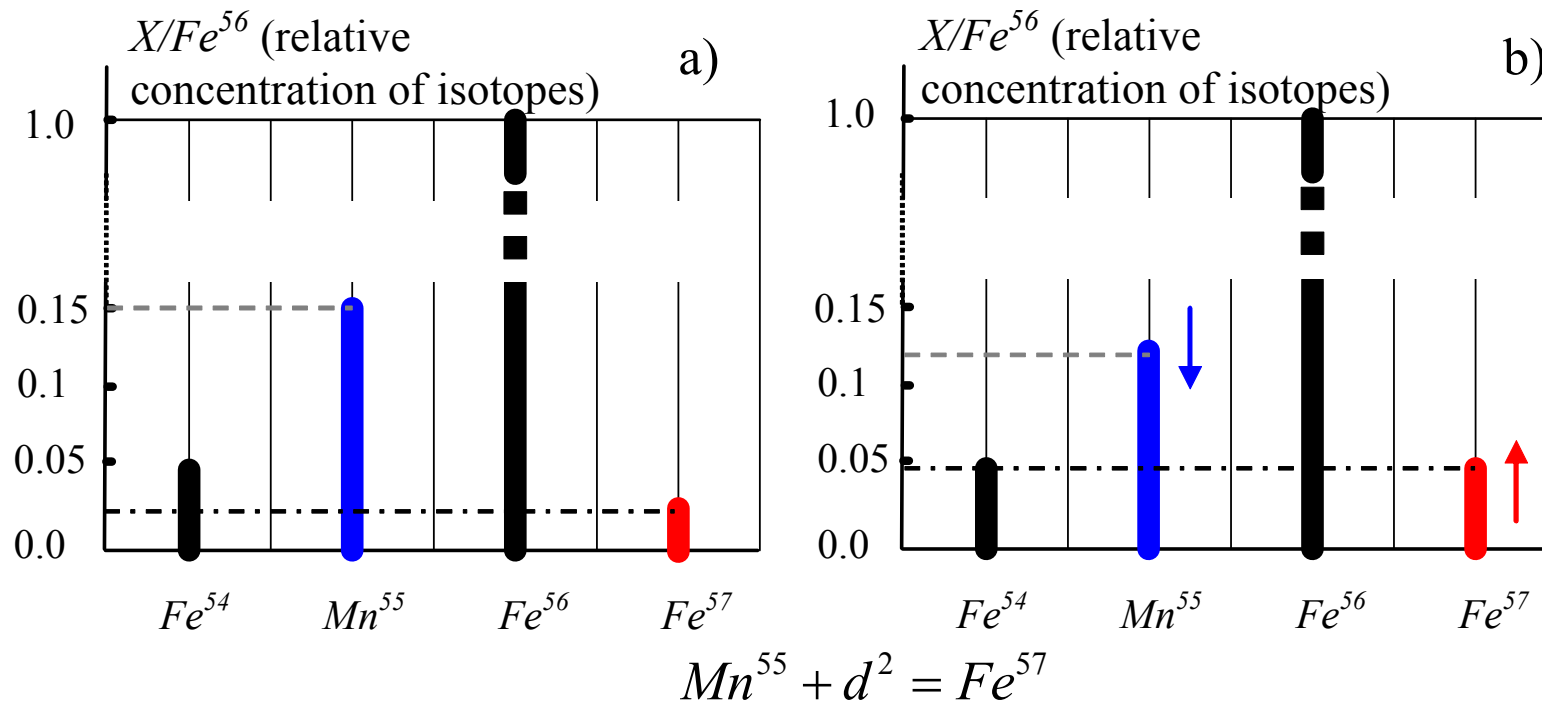
Mass-spectrum of iron-region of microbiological associations (dried biological substances) that were grown in control nutrient medium with H_2O and Mn^{55} (case a)) and in experimental nutrient medium with D_2O and the same quantity of Mn^{55} isotope (case b)) .Here $X=Fe^{54};Mn^{55}; Fe^{57}$ **The process of increasing (↑) of concentration of Fe^{57} isotope is accompanied by decreasing (↓) of concentration of Mn^{55} isotope**

Table 2. **Parameters of mass-spectroscopy investigation of control and transmutated cultures.**

Isotope (natural concent-ration)	Natural isotopic ratio (in relation to Fe^{56})	Concentration in dried biological substance in control experiment: H_2O + $MnSO_4$ + nutrient medium	Isotopic ratio in control biological substance	Concentration in dried biological substance in experiment on transmutation: D_2O + $MnSO_4$ + nutrient medium, (normalized)	Isotopic ratio in the experiments on transmutation
Mn^{55}, 100%	–	0.15 ± 0.01	$Mn^{55}/Fe^{57} = 6.6$	0.13 ± 0.01	$Mn^{55}/Fe^{57}= 7.7$
Fe^{56}, 91.7%	1	1	1	1	1
Fe^{57}, 2.2 %	$Fe^{56}/ Fe^{57} = 41.7$	0.024 ± 0.002	$Fe^{56}/ Fe^{57} = 42.5$	0.051 ± 0.003	$Fe^{56}/ Fe^{57} = 9.5$

Experiments on transmutation of stable Cs^{133} isotope

Expected reaction $Cs^{133}+p=Ba^{134}$

The studies were conducted on the simulator of liquid radioactive waste (water solution of $CsNO_3$ with concentration of 0.3 g/liter of stable Cs^{133} isotope). The resulting solution, containing dissolved $CsNO_3$ salt and micro and macro chemical elements that are necessary for the growth of microorganisms, was divided into several portions, 500 ml bottles and placed in 1 liter bottles. To each bottle 200 ml of a liquid solution of syntrophic microbiological association was added.
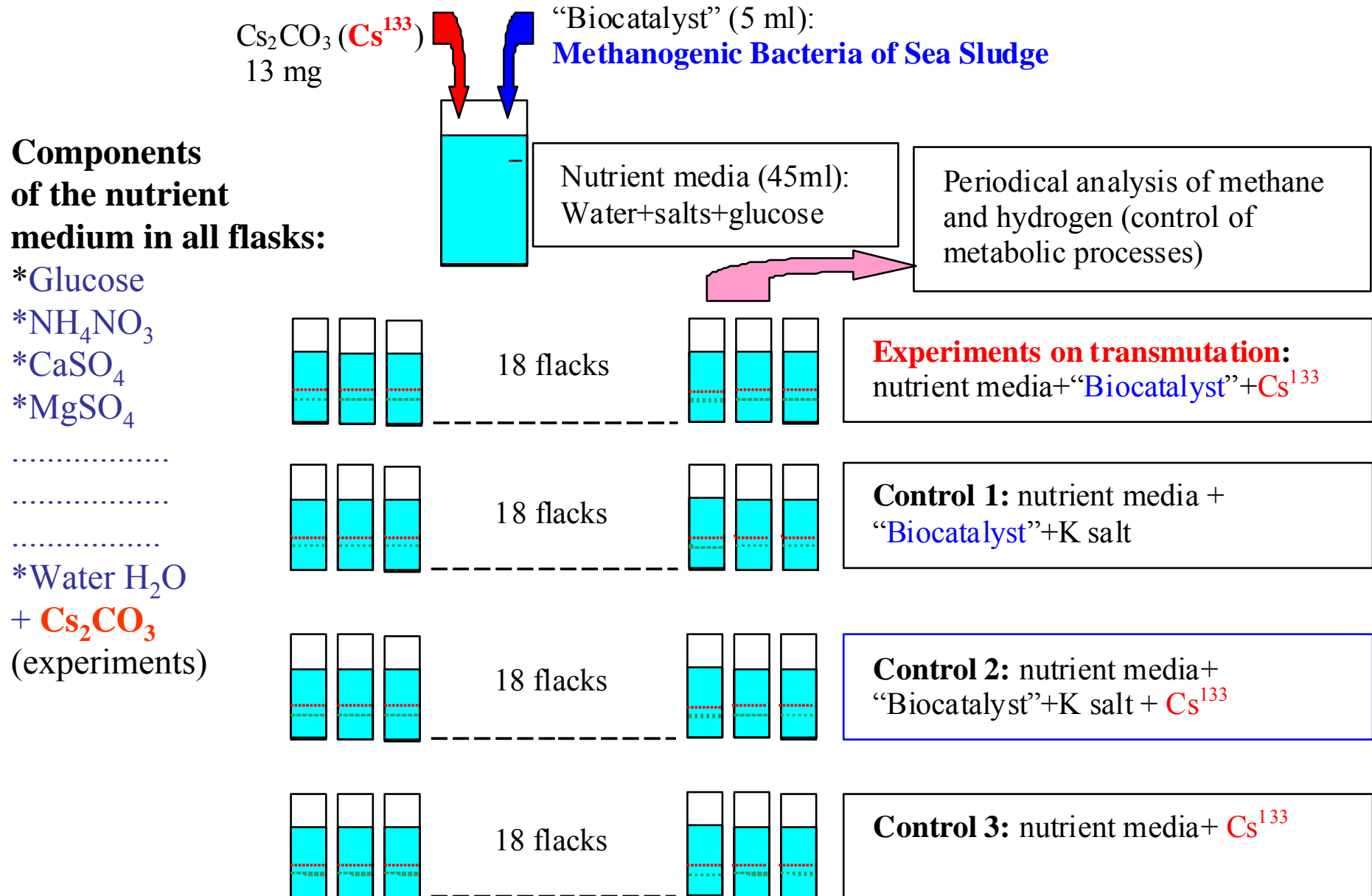The temperature during the growth of cultures was 30-45 C.

View of bioreactors (bottles with aerobic syntrophic association) prior to the addition of cesium in medium

Thermostatic box for bioreactors .

The scheme of experiments on transmutation of heavy stable isotopes by anaerobic cultures.   Expected reaction $Cs^{133}+p=Ba^{134}$

Cs_2CO_3 (Cs^{133}) 13 mg

"Biocatalyst" (5 ml): **Methanogenic Bacteria of Sea Sludge**

Nutrient media (45ml): Water+salts+glucose

Periodical analysis of methane and hydrogen (control of metabolic processes)

Components of the nutrient medium in all flasks:
*Glucose
*NH_4NO_3
*$CaSO_4$
*$MgSO_4$
....
....
....
*Water H_2O
+ Cs_2CO_3
(experiments)

18 flacks — **Experiments on transmutation:** nutrient media+"Biocatalyst"+Cs^{133}

18 flacks — **Control 1:** nutrient media + "Biocatalyst"+K salt

18 flacks — **Control 2:** nutrient media+ "Biocatalyst"+K salt + Cs^{133}

18 flacks — **Control 3:** nutrient media+ Cs^{133}

Preparation of experimental cells with nutrient medium and Cs^{133} salt

Hermetization of flasks with working mixture

Replacing the air to argon

The view of flasks in 96 hours after the start of the experiment

Experimental flask

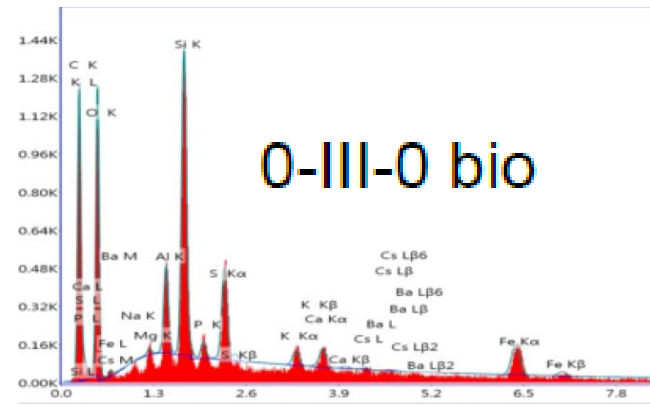Control (3) flask
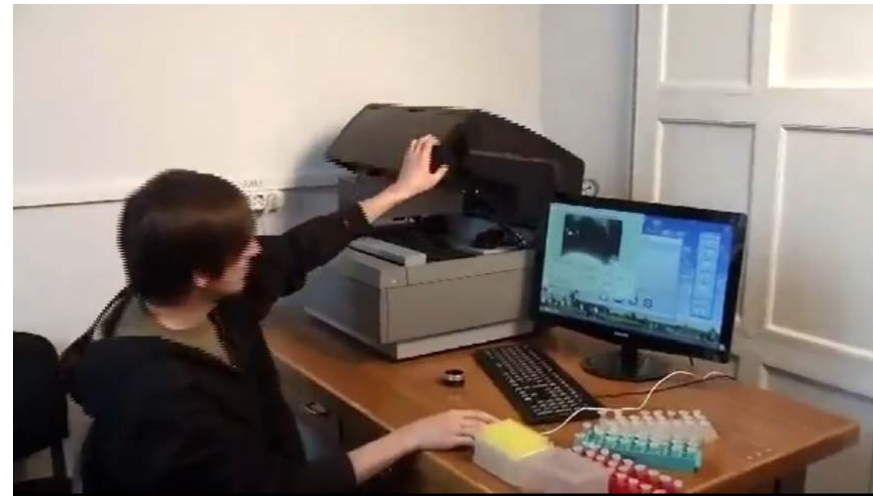
X-ray fluorescence analyzer

The equipment used for the analysis of the process of transmutation of stable cesium

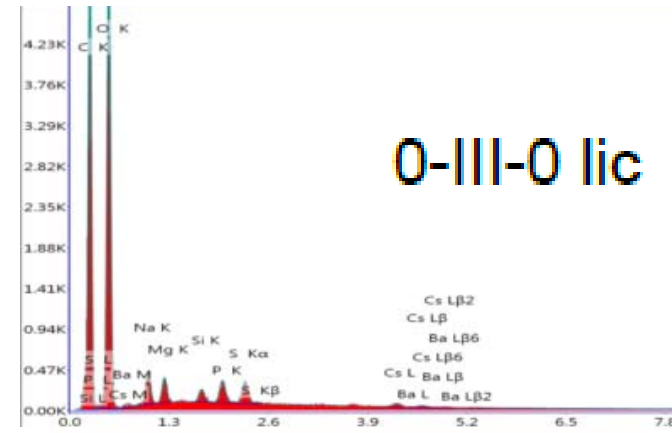Analysis of Ba^{134} - Atomic Emission Spectrometry "Prodigy High Dispersion ICP" with inductively coupled plasma

Analysis of Cs^{133} - High-Resolution Continuum Source atomic absorption *spectrometer* nov AA 350 (firm Analytikjena)
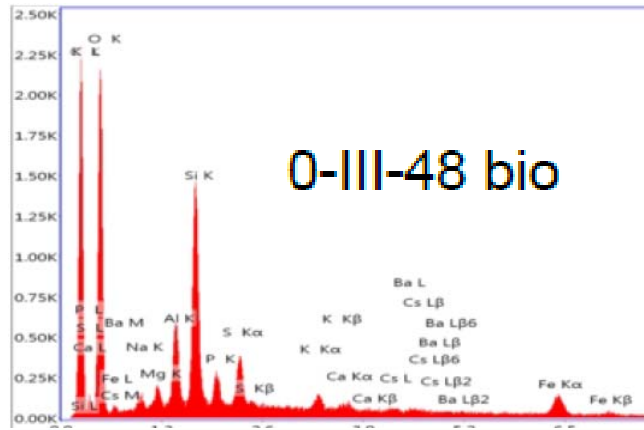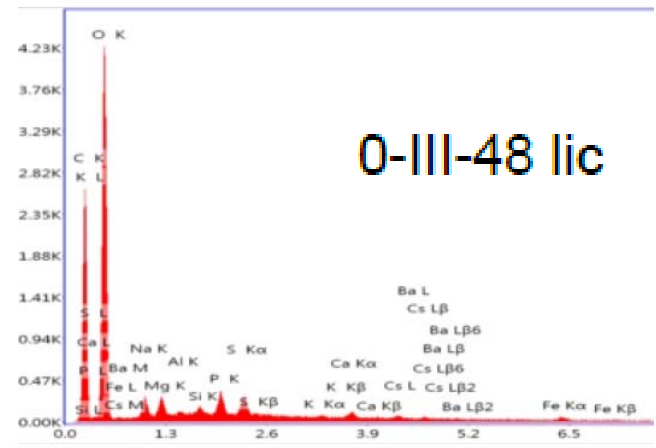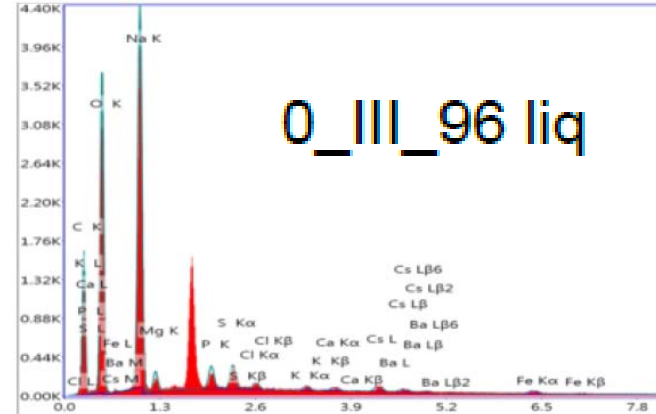
Change in the elemental composition
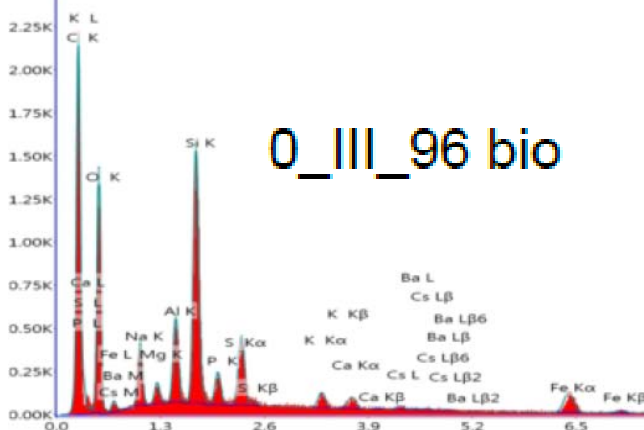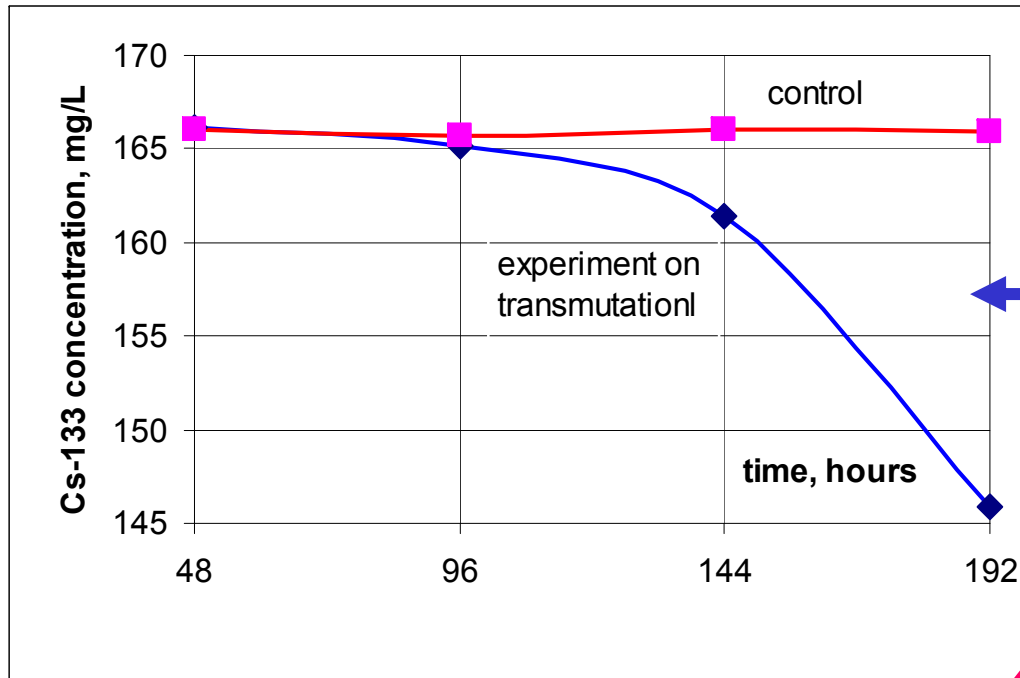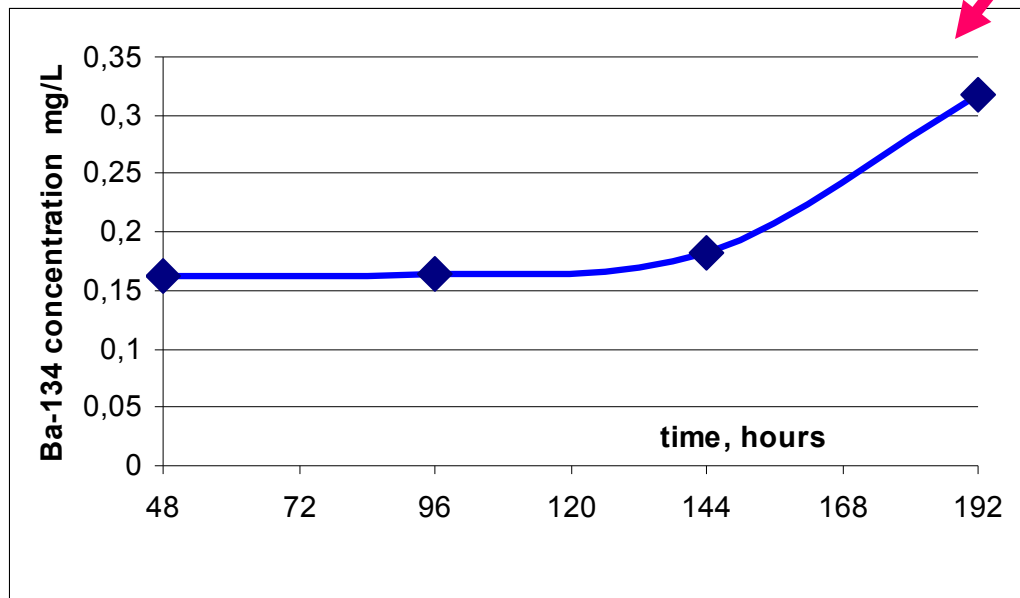of growing culture   and   dried nutrient medium

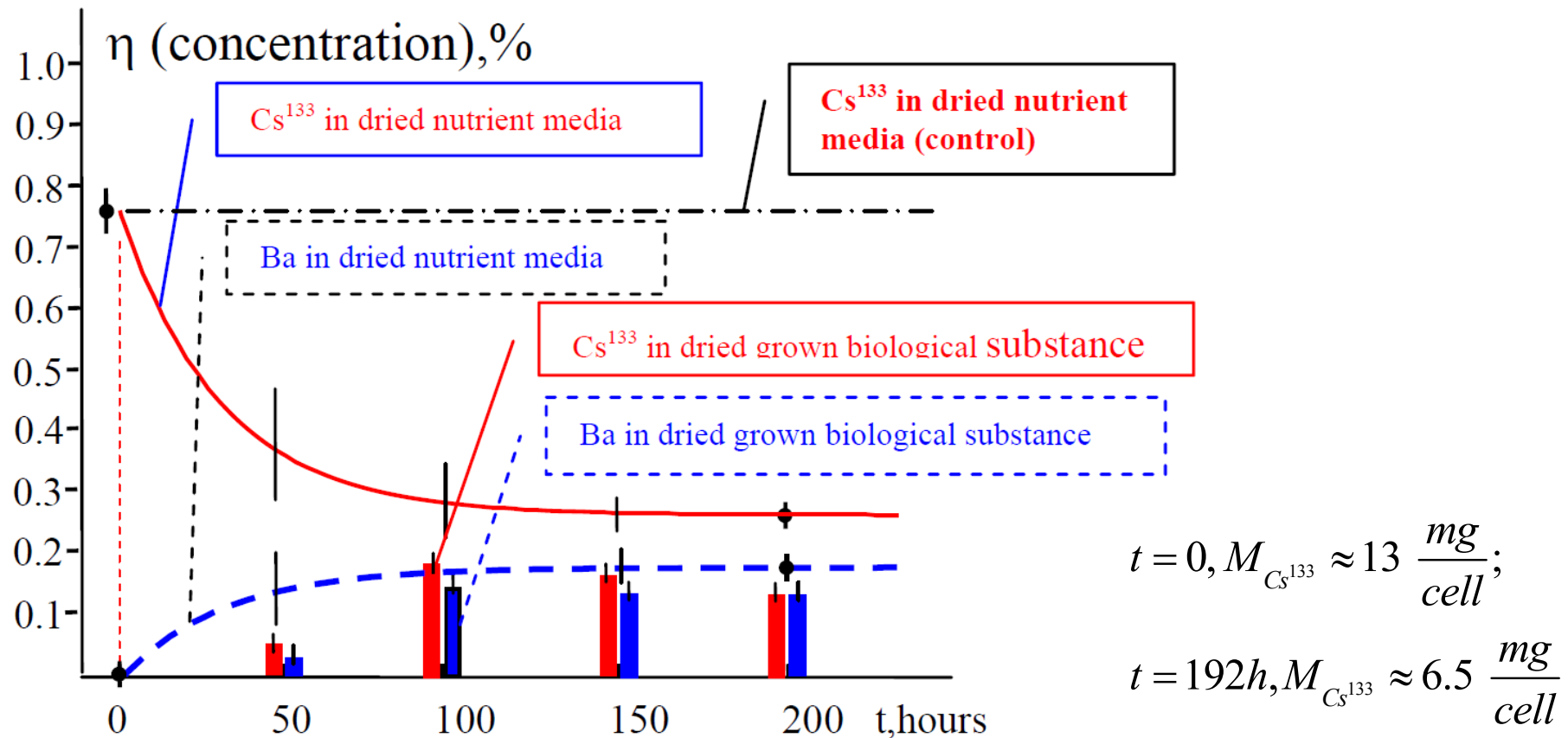# Experimental results of Cs^{133} isotope transmutation

Deacrease of Cs^{133} concentration versus time in the liquid sample in the experiments on transmutation. Control experiment was conducted without addition of microcultures.

Increase of Ba^{134} isotope concentration versus time after evaportation of concentrated liquid samples taken from the bottom part of bottle (plastic bioreactors) together with precipitate in the experiments on transmutation. The maximum amount of barium was found in the samples taken from the bottom of the bottle together with precipitate . This is due to the presence of carbon dioxide in the bottle and the transformation of barium ions in poorly soluble barium carbonate

Transmutation Cs^{133} to Ba

η (concentration),%

Cs^{133} in dried nutrient media

Cs^{133} in dried nutrient media (control)

Ba in dried nutrient media

Cs^{133} in dried grown biological substance

Ba in dried grown biological substance

$t = 0, M_{Cs^{133}} \approx 13 \dfrac{mg}{cell};$

$t = 192h, M_{Cs^{133}} \approx 6.5 \dfrac{mg}{cell}$

$$\alpha = \frac{(\eta_{Cs}^{Water})_{t=0} - (\eta_{Cs}^{Water} + \eta_{Cs}^{Bio})_{t=t_0}}{(\eta_{Cs}^{Water})_{t=0}} \approx \begin{cases} 0.43 \pm 0.05, t_0 = 96h \\ 0.50 \pm 0.05, t_0 = 192h \end{cases}$$

The rate of Cs^{133} to Ba transmutation is the following:

$$\lambda = N(Ba) / N(Cs^{133}) \Delta t \approx 10^{-6} \ s^{-1}$$

(synthesized Ba nuclei per s and per Cs^{133} nucleus)

Experiments on controlled decontamination of active isotopes in biological cells


Rovno APS (Ukraine). **Beautiful place?**

Problems of modern nuclear industry

Now in the world there are 368 active industrial nuclear reactors (USA- 104; France-58, Japan-50,Russia-33, S.Korea-21, Ukraine-15);
63 - are building, 138 – are closed.
 Now in the world there are **more than 325 000 tons of spent reactor fuel (high-level radioactive waste) (in USA – 110 000 tons) and 15 000 tons/year.** Besides, in each reactor there are thousands tons of highly active water (more than **1 million tons of highly active water in the world**).
Besides, in the world there are about **10 millions tons of low active waste**.
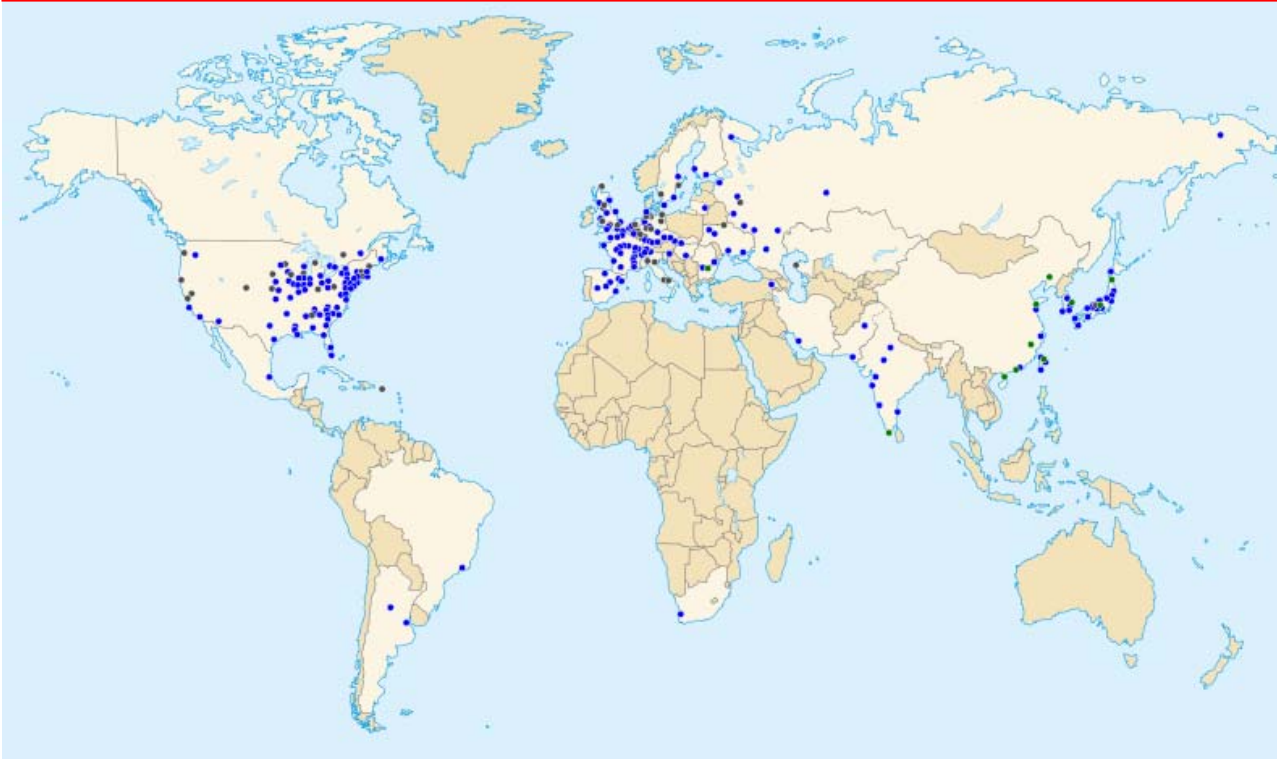
The typical components of high-level radioactive reactor waste

Isotope	Half-life	Activity (in relation to Pu^{239})	Main decay mode
Sr^{90}	28.5 years	Q=230	β-
Zr^{95}	64 days	Q = 5800	β-
Nb^{95}	35 days	Q = 5700	β-
Mo^{99}	66 hours	Q = 6100	β-
Ru^{103}	39 days	Q = 3800	β-
Ru^{106}	373 days	Q = 860	β-
Sb^{125}	2.8 years	Q = 150	β-
I^{131}	8 days	Q = 3100	β-
Cs^{134}	2 years	Q = 170	β-
Cs^{137}	30.03 years	Q = 260	β- (and γ)
Ce^{144}	285 days	Q = 3900	β-
Eu^{154}	8.8 years	Q = 14	β-
Pu^{238}	87.7 year	Q = 1.3	α
Pu^{239}	24000 years	Q = 1	α
Pu^{240}	6550 years	Q = 1.5	α
Pu^{241}	14.4 years	Q = 180	α
Am^{241}	432 years	Q = 0.16	α
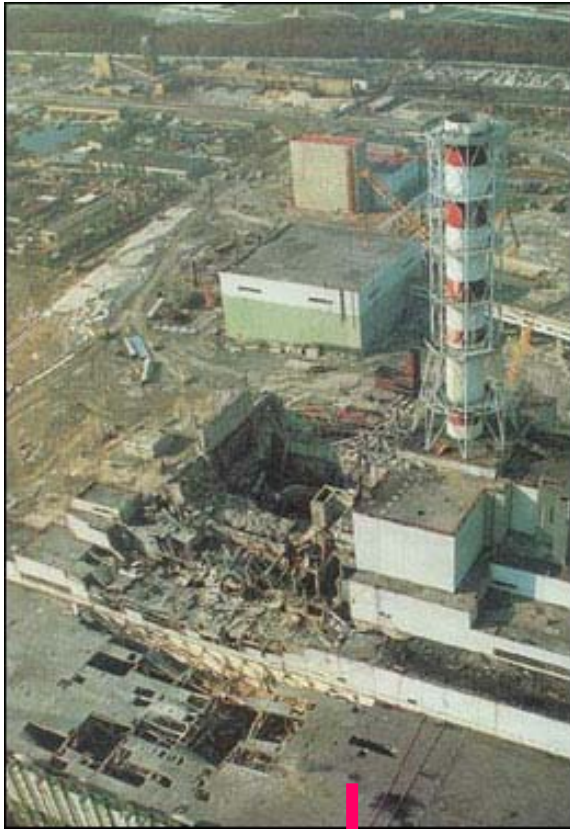
The April 26, 1986 accident at Chernobyl.

Four hundred times more radioactive material was released than in the atomic bombing of Hiroshima.
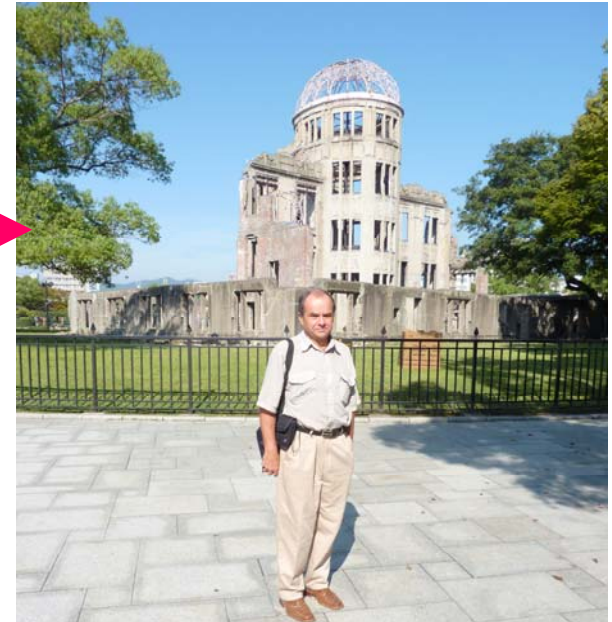
Effects of FUKUSHIMA

Fukushima area! сообщает

Radioactive water and soil: water – 380 000 tons+350 tons/day; soil - about 500-700 ktons
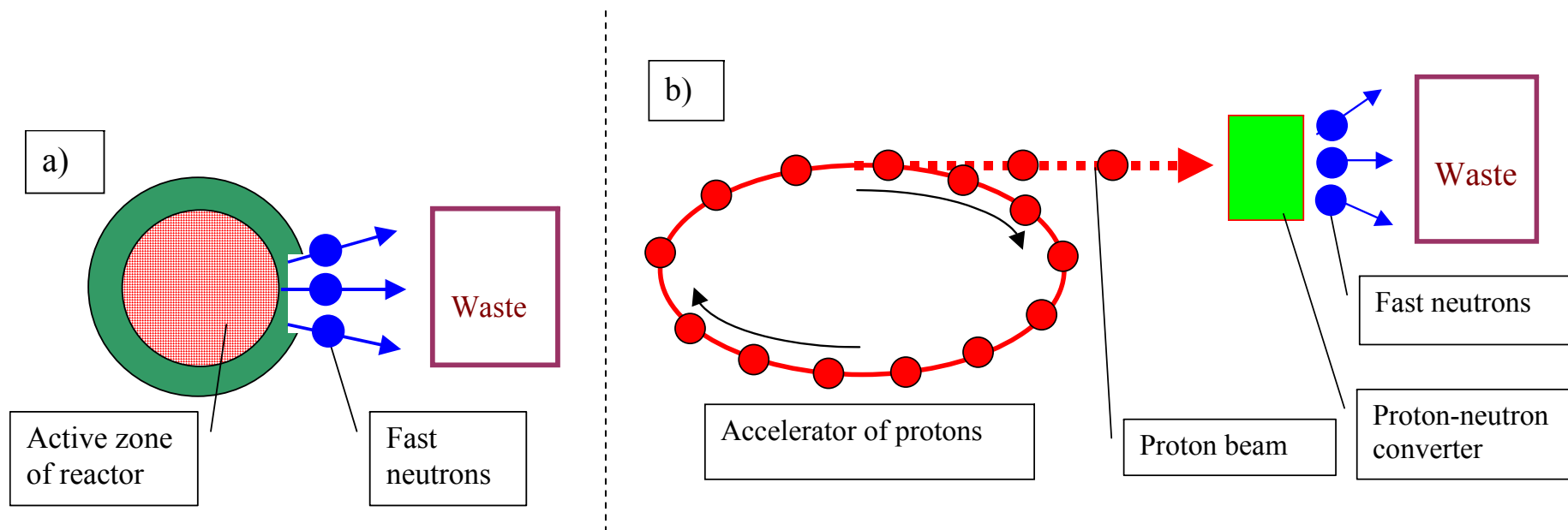
現在の放射線量 0.18 μSv/h

Fokushima city today

There are different possible methods of utilization of these waste.
Traditional way of utilization (transmutation of radioactive waste to different stable isotopes by action of neutron beams created in proton-neutron converters) are very expensive.

The total cost of both scientific and technologies parts of such solution of the utilization problem (USA, Japan, Russia, France, UK, S.Korea) is about $30-50 billions during 2010-2050!

Another essential drawback of this program is the following: at such neutron action on highly radioactive waste a great amount of additional low active waste is formed in environment.

a) Active zone of reactor — Fast neutrons — Waste

b) Accelerator of protons — Proton beam — Proton-neutron converter — Fast neutrons — Waste
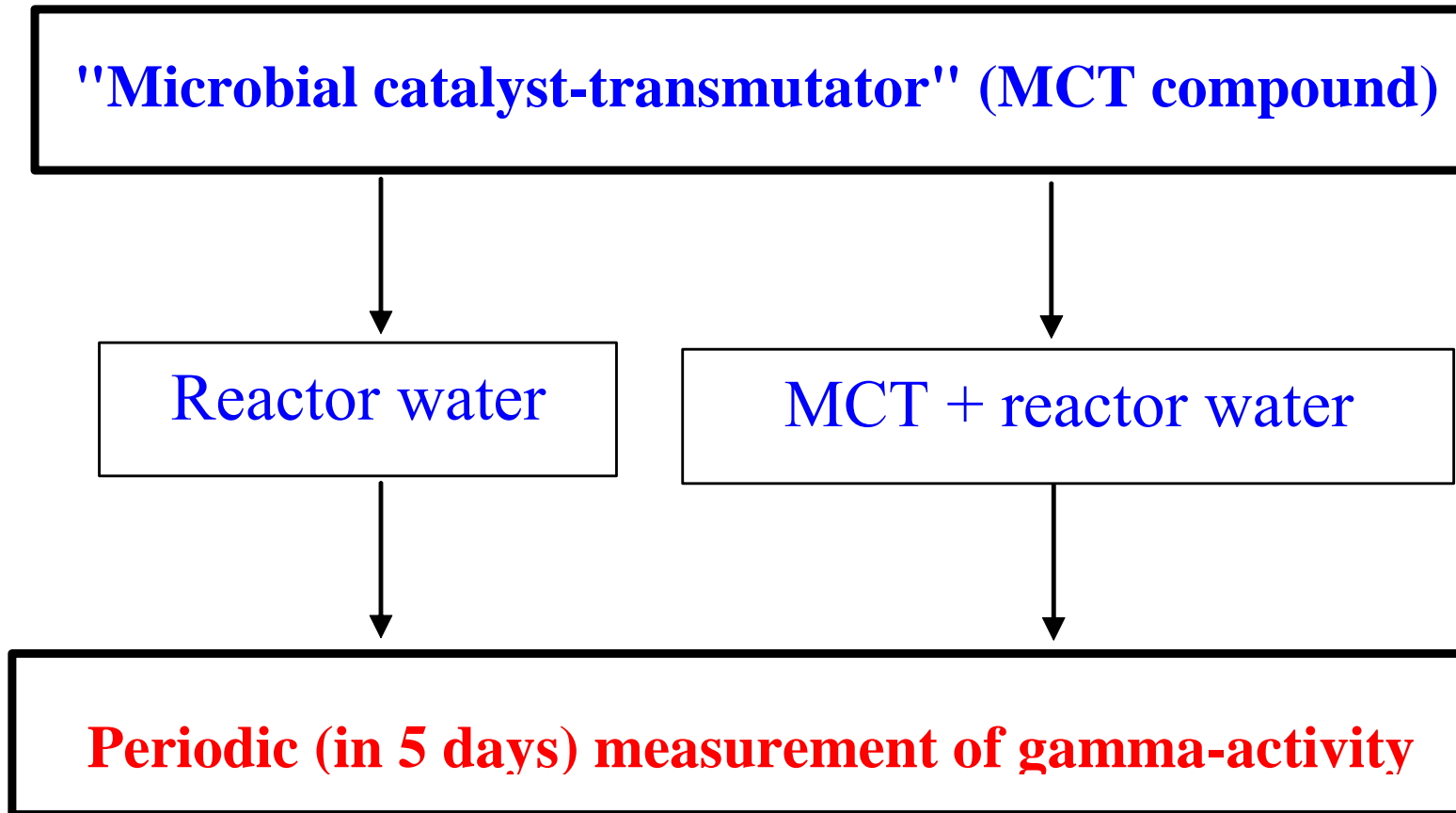
Deactivation of reactor water in biological cells

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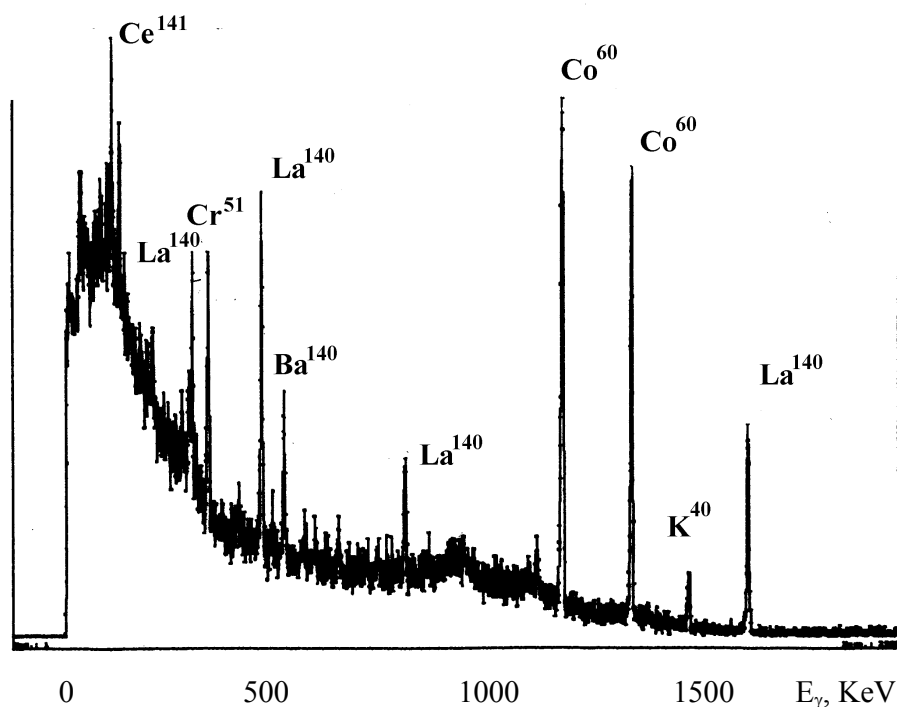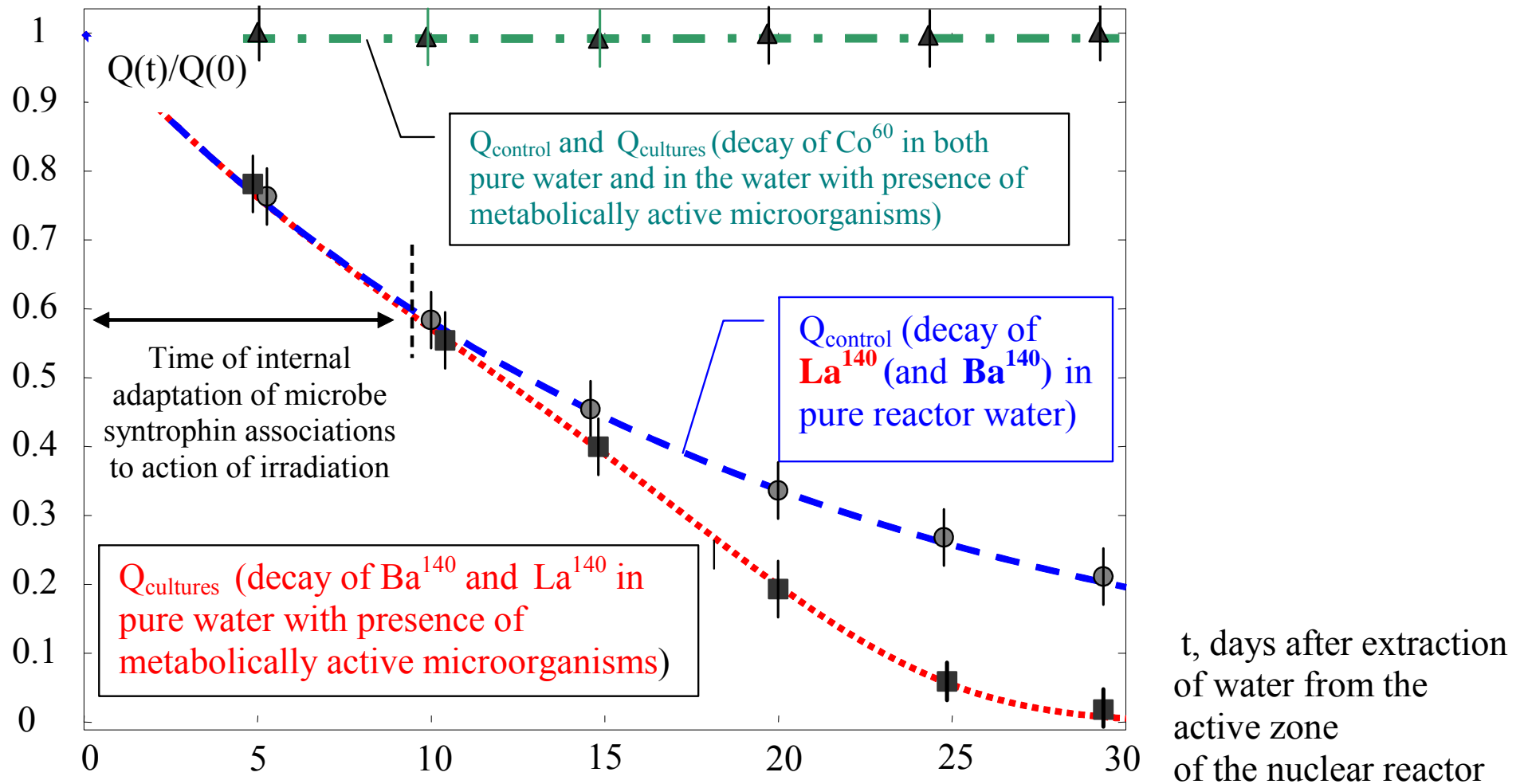

Spectrum of gamma-radiation of distilled water from first contour of water-water atomic reactor of Kiev Institute for Nuclear Research (10th day after extraction from the active zone).

Deactivation of reactor water in biological cells

"Microbial catalyst-transmutator" (MCT compound)

Reactor water

MCT + reactor water

Periodic (in 5 days) measurement of gamma-activity

Study of utilization of reactor water in microbiological cells

Change of activity Q(t) of the same reactor Ba^{140}, La^{140} and Co^{60} isotopes in the experiment on transmutation (activity Q$_{cultures}$ in pure reactor water with presence of metabolically active microorganisms) and in the control one (activity Q$_{control}$ in the same pure reactor water without microorganisms)

Studied La-140 isotope has short life-time 40.3 hours and is nonstable
daughter isotope of Ba-140 radioactive isotope that has life-time about
τ_{Ba140}= 12.7 days:
Ba-140 $\rightarrow$ La-140 + β- + ν^* $\rightarrow$ Ce-140 (stable) + β- + ν^*
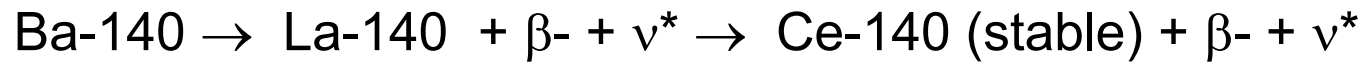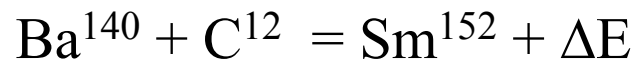
Initial activities of the Ba-140 and La-140 isotopes (on the 10th day after
extraction of water from the active zone of the nuclear reactor) were

$$Q_{Ba-140} = 1.46.10^{-6} Curie/l$$

$$Q_{La-140} = 2.31.10^{-7} Curie/l$$

The possible way of radioactive Ba^{140} isotope transmutation to the stable state
is
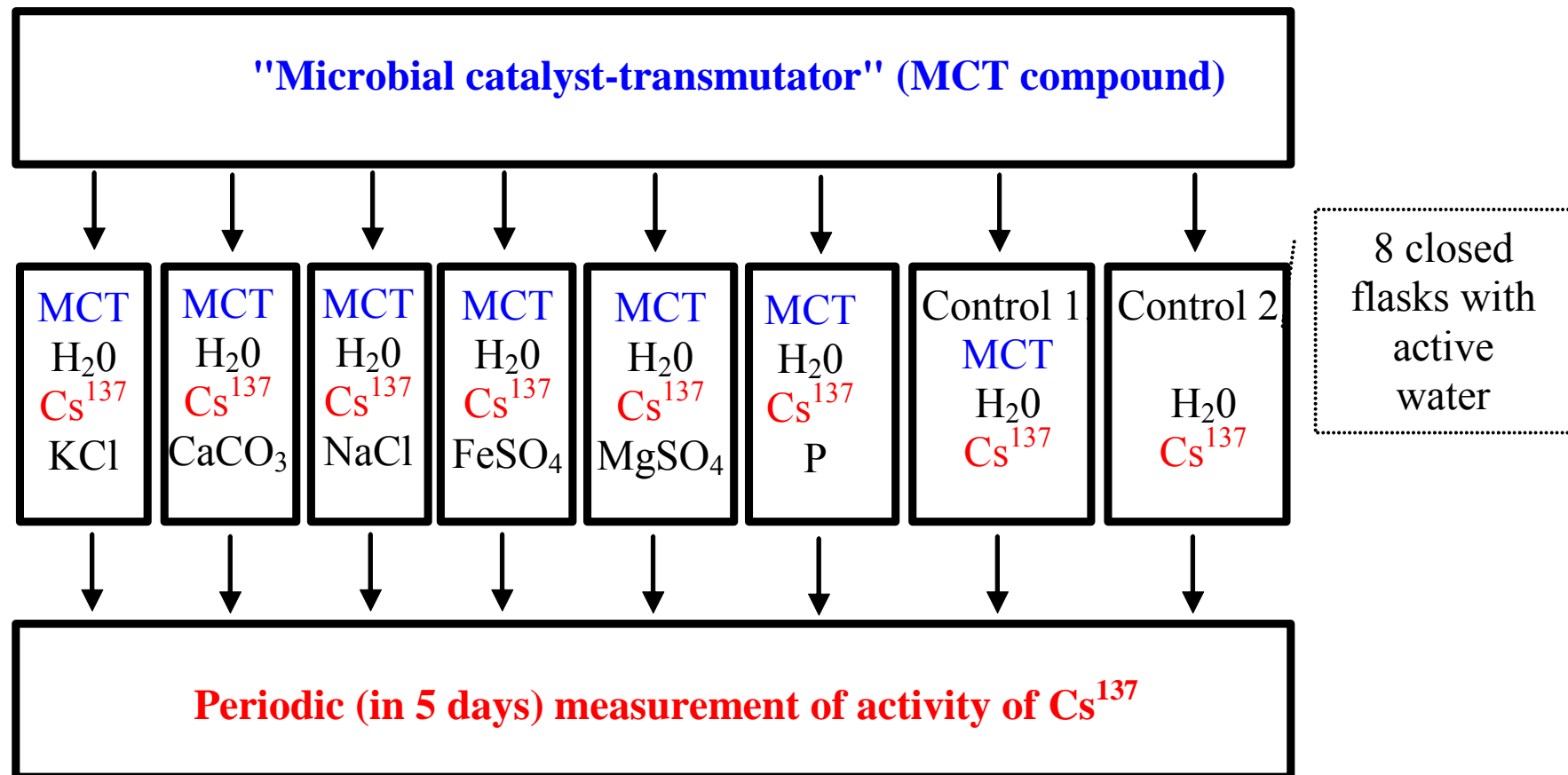$Ba^{140} + C^{12} = Sm^{152} + \Delta E$
These reactions are energy favourable and
$\Delta E = E(A_{Ba}, Z_{Ba}) + E(A_C, Z_C) - E(A_{Sm}, Z_{Sm}) = 8.5$ MeV is positive.

*The Sm(2+) and Ca(2+) ions are chemically alike and have the approximately
same ionic radiuses of divalent state ($R_{Sm} \approx 1.2$ A, $R_{Ca} \approx 1.06$ A).
Substituted element Ca is among several vitally necessary elements. Ions of
created Sm(2+) elements can substitute Ca(2+) ions while microbiological
cultures are growing.*

Deactivation of Cs^{137} isotope in biological cells

The research has been carried out on the basis of the same distilled water that contained long-lived reactor isotope Cs^{137} (activity $\approx 2.10^4$ bq), In our experiments 8 identical closed glass flasks with very thin walls and with 10 ml of the same active water in each were used. The MCT was placed in 7 glass flasks.

"Microbial catalyst-transmutator" (MCT compound)								
MCT H$_2$0 Cs^{137} KCl	MCT H$_2$0 Cs^{137} CaCO$_3$	MCT H$_2$0 Cs^{137} NaCl	MCT H$_2$0 Cs^{137} FeSO$_4$	MCT H$_2$0 Cs^{137} MgSO$_4$	MCT H$_2$0 Cs^{137} P	Control 1 MCT H$_2$0 Cs^{137}	Control 2 H$_2$0 Cs^{137}	8 closed flasks with active water

Periodic (in 5 days) measurement of activity of Cs^{137}

*Study of utilization of active isotopes at different conditions*

In six different flasks different pure K, Ca, Mg, Na, Fe and P salts as single admixture were added to the active water. These chemical elements are vitally necessary for any cultures. Each of these replacements completely blocks the channel of transmutation with the use of all biochemical analogs of the concrete chemical element. The results obtained confirmed the importance of such replacements.

Two additional flasks were used for control experiments: one flask contained the active water and MCT (but without salts) and in another one was only active water (without salts and MCT).

The cultures were grown at the temperature 20^0 C. Activity of all closed flasks has been measured every 7 days by precise amplitude Ge detector.

Amplitude Ge gamma-detector

Investigated flask with active water

Gamma-radiation of Cs^{137}

Experiments with non-isolated active isotope Cs-137 were performed at Scientific Research Center of Chernobyl zone. During the process of measuring of spectrum the special screened box with very low level of natural ionizing radiation background was used.
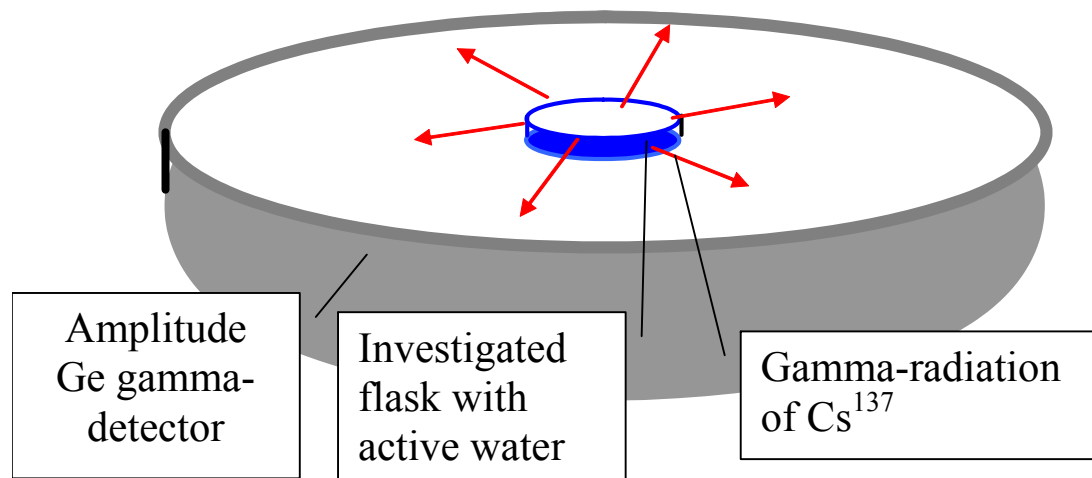
RESULTS OF EXPERIMENTS

We have observed increased rates of decay of Cs137 isotope in all experiments with MCT and with the presence of different additional salts during 100 days.
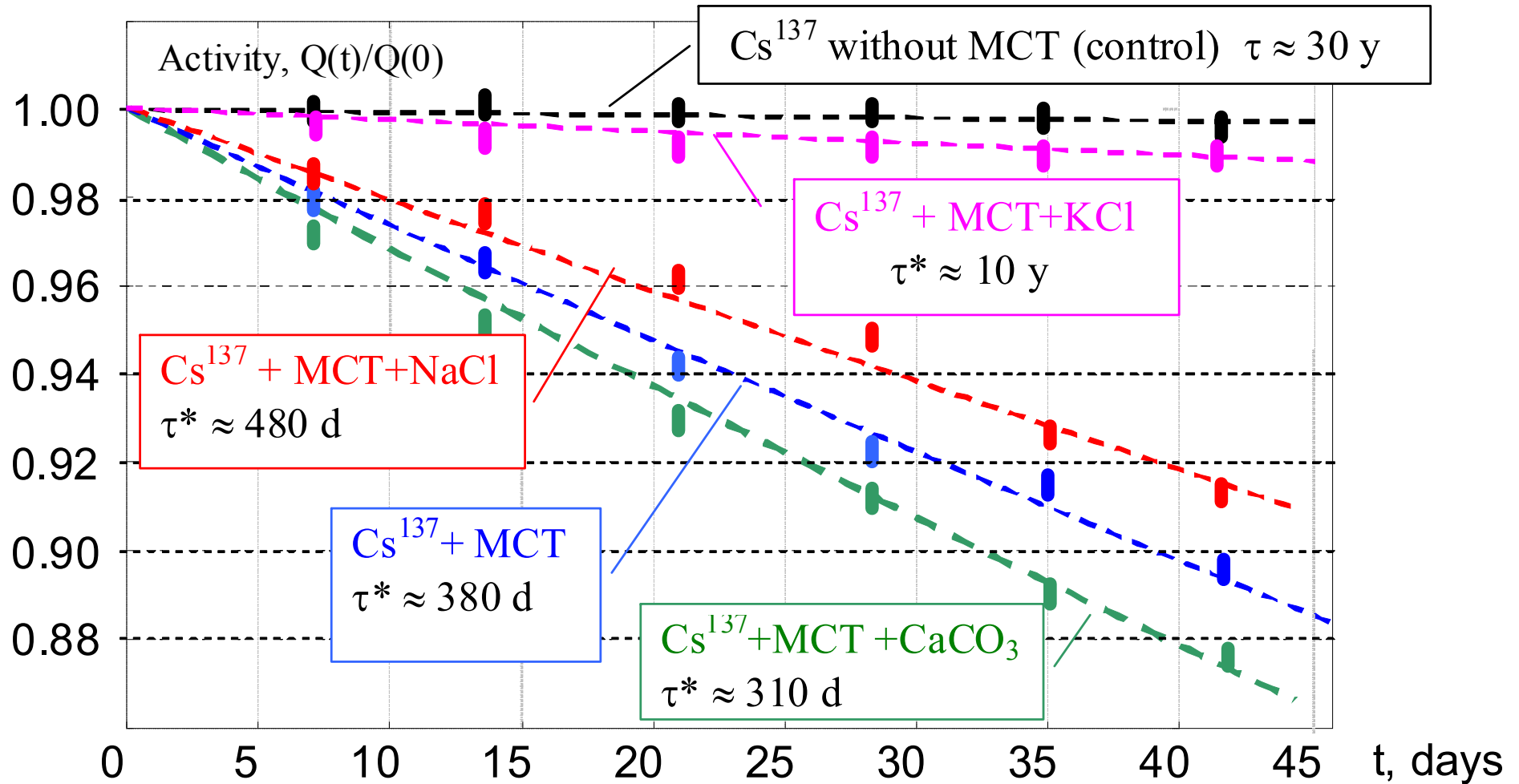
The most rapidly increasing decay rate, which occurred with a lifetime $\tau^* \approx 310$ days (involving an increase in rate, and decrease in lifetime by a factor of 35 times) was observed in the presence of Ca salt!

The same date are presented in the Table.

Deactivation of different active isotopes in optimal experiment

(MCT + active water with presence of Cs^{137} + $CaCO_3$ salt)

Isotope	Energy, keV	Start of experiments N_1, registered events per 10^3 s	Intermediate finish of experiments (duration 100 d) N_2, registered events per 10^3 s	Error (absolute/ relative)	Natural decay per 100 d	Change $(N_2-N_1)/N_2$
Cs^{137}	661.7	266900	216800	±478 (±0.2%)	-0.6 %	-24 %

We have observed increased rates of decay of Cs137 isotope in all experiments with MCT and with the presence of different additional salts during more than 100 days.

In the control experiment (flask with active water but without MCT), the "usual" law of nuclear decay applies, and the life-time was about 30 years.

The most rapidly increasing decay rate, which occurred with a lifetime $\tau^* \approx 310$ days (involving an increase in rate, and decrease in lifetime by a factor of 35 times) was observed in the presence of Ca salt! In the presence of an abnormal (redundant) quantity of potassium in the nutritious media, the process of Cesium transmutation becomes very weak and the life-time of the decay was about 10 years.

The possible reaction of Cs^{137} isotope utilization and transmutation is

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

The result of this reaction is the creation of stable Ba^{138} isotope. This reaction is energy favourable ($\Delta E = 5.58$ MeV is positive).

The Ba^{2+} and K^+ ions are chemically alike and have the approximately same ionic radiuses of divalent state ($R_{Ba} \approx 1.4$ A, $R_K \approx 1.33$ A). Substituted element K is among several vitally necessary elements. Ions of created Ba^{2+} elements can substitute K^+ ions in metabolic process while microbiological cultures are growing.
Such substitution is more effective that "direct" replacement of potassium to caesium because the ionic radius of caesium is $R_{Cs} \approx 1.65\text{-}1.69$ A that is larger than the ionic radius of $R_K \approx 1.33$ A of potassium.
By the way such substitution was observed earlier in experiments with microculture Blastocladiella emersonii [Van Brunt J., Caldwell J. H., Harold F. M. Circulation of potassium across the plasma embrane of Blastocladiella emersonii : K-chanel // J. Bacteriol., 1982, v.150, N 3, pp. 1449-1561].
In these experiments the substitution of K^+ ions to Rb^+ and Ba^{2+} ions have taken place. These ions can replace each other in transporating ions through membrane to a cell.

Table 5.3 Microorganisms' interaction with macro elements and their stereochemical analogues

Stereochemical analogues		Micro-organisms	Type of interaction in a biological system	Source
Macroelement	Analogue metal			
1. K^+	Rb^+	*Blastocladiella emersonii*	Common transporting system of ions to a cell	Kropf, Harold, 1982
2. K^+	Rb^+, Ba^{2+}	*B. emersonii*	Common transporting system of ions from a cell	Van Brunt, 1982
3. K^+	Rb^+, Cs^+	*Escherichia coil*	Common transporting system of ions to a cell	Bossemeyer, 1989
4. K^+	Rb^+	*Anabaena variabilis*	Common transporting system of ions to a cell	Reed, 1981
5. K^+	Rb^+	*Saccharomyces cerevisiae*	Common transporting system of ions to a cell	Rodrigues-Navarro, 1984
6. Mg^{2+}	Co^{2+}, Ni^{2+}	*Klebsiella pneumoniae*	Common transporting system of ions to a cell	Ainthworth, 1980
7. Mg^{2+}	Mn^{2+}, Cd^{2+}	*Bacillus subtilis*	Common transporting system of ions to a cell	Burke, 1988
8. Mg^{2+}	Mn^{2+}, Co^{2+}	*Escherichia coli*	Co^{2+} inhibits transporting Mn^{2+} to a cell	Laddaga, 1985
9. Fe^{2+}	Co^{2+}	*Acidophilium sp.*	Competition for transporting system of ions to a cell	Don, 1989
10. Ca^{2+}	Sr^{2+}	*Saccharomyces cerevisiae*	Common transporting system of ions to a cell	Borst-Pauwels, 1986
11. Ca^{2+}	Zn^{2+}, Cd^{2+}	*Escherichia coli*	Zn^{2+} activates transporting of Cd^{2+} to a cell	Sacaguchi, 1981

Additional experiments on transmutation of radioactive Cs^{137} isotope $\mathrm{\color{red}{Cs^{137}+p=Ba^{138}}}$ were conducted in 2015-2016 on the base of **our microbiological, chemical and isotopic components** and using **our theoretical models, our methodology and our control** in the independent specialized well known nuclear physics center *Bochvar High-Technology Scientific Research Institute for Inorganic Material (VNIINM , Russia)*

Before the start of experiments several bottles with an initial water solution containing necessary chemical and aerobic microbiological elements (syntrophic association similar to the case of stable Sc^{133} transmutation) were prepared .

• To each bottle an water solution of radioactive cesium Cs^{137} was added. This amount was chosen to provide the level of 10^4 Bq of radioactive cesium for each bottle.

• The total volume of solution in each bottle, prepared for experiments, was 750 ml.

• The temperature during the cultures growth was 30-45 C.

- Radiospectroscopic measurements of gamma-activity of Cs^{137} isotope were performed on the device "Inspetor 100" company "CANBERRA" with the detection unit "IPROS-2" NaI scintillation detector with a diameter of 50 mm.

- At measurements of Cs^{137} activity the spectral gamma-emission line with energy 661.65 keV was used.

- In order to reduce measurement errors of gamma activity, associated with a spatial redistribution of Cs137 isotope in the bottles, the measurements were performed at small and at large distances and averaged

- Accuracy of measuring the activity in the used range ($Q \approx 10^4$ Bq/bottle) was not less than 100 Bq ($\Delta Q_{min}/Q = 1\%$)..

Averaged experimental results of transmutation of Cs^{137} isotope
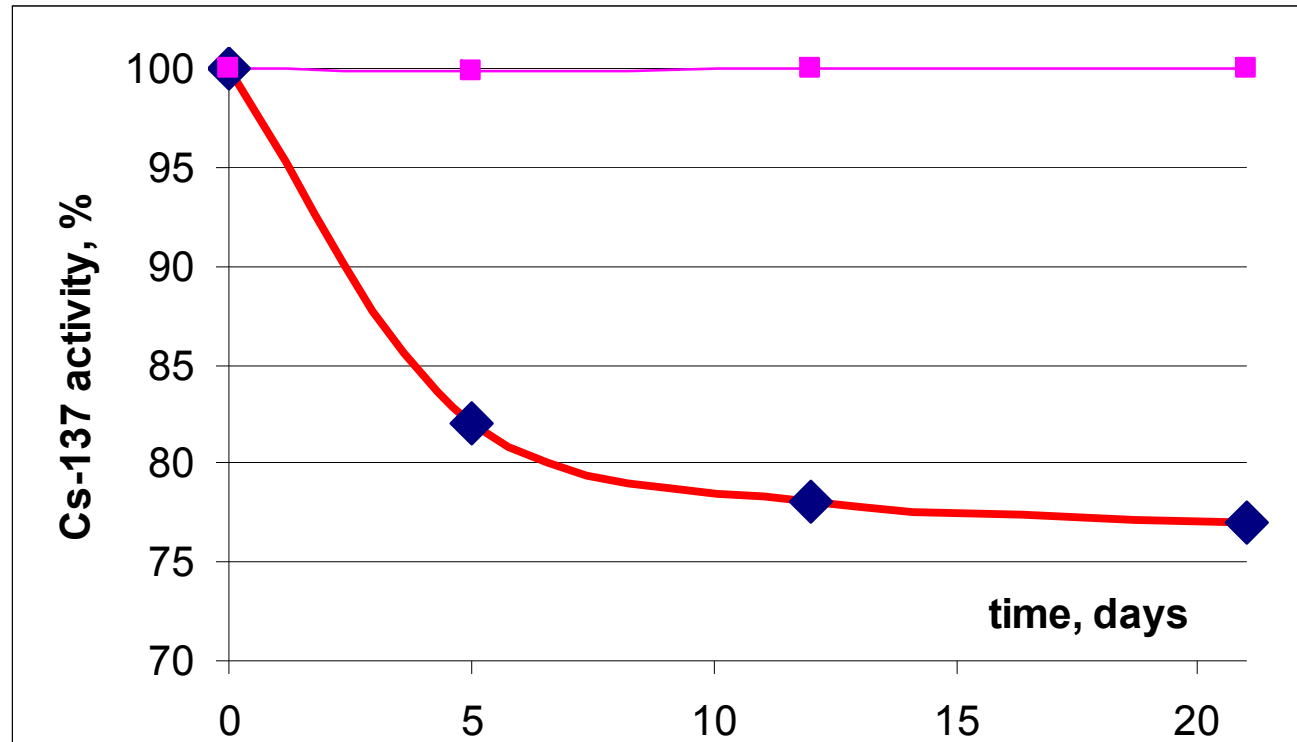
Deacrease (up to 23%) of **averaged** (by all plastic bioreactors) gamma-activity of Cs^{137} isotope versus time in the experiments on transmutation.
Control experiment was conducted without addition of microcultures.

The rate of Cs^{137} + p = Ba^{138} deactivation reaction:

$$\lambda_{max} = \frac{1}{N_{Cs^{137}}(t)} \frac{dN_{Cs^{137}}(t)}{dt} \approx 2.10^{-7} \text{ deactivated } Cs^{137} \text{ nuclei per s and per single } Cs^{137} nucleus$$

For further stages (up to 100%) of Cs^{137} isotope transmutation it is necessary to make the operational changes to the composition of the nutrient medium during transmutation.

The most essential (up to 40% and 70% in two weeks) decrease of gamma-activity of Cs^{137} isotope versus time was observed in selected (more optimal) plastic bioreactors in the same series of experiments on transmutation.
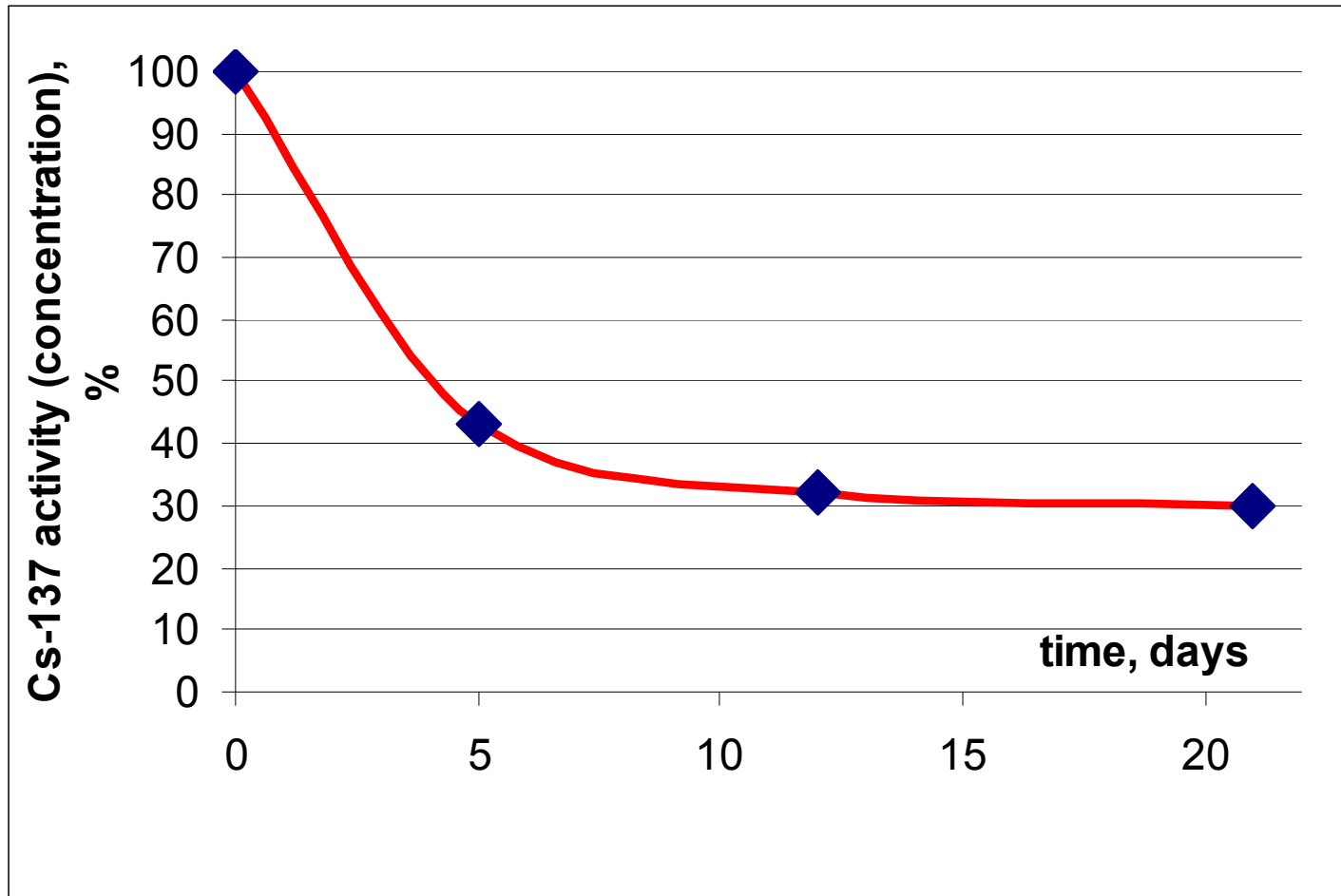
This result may be explained by the presence of biologically more active fragments in the compound syntrophic association.

Mentioned above experiments on transmutation of both **stable** and **radioactive isotopes** were conducted during 1993-2017 by the members of our scientific team in:

- **"Shelter" object in Chernobyl**,
- **Kiev National Shevchenko University,**
- **Kiev Institute of microbiology,**
- **Kiev Institute for nuclear Research**
- **Moscow Gamaleya Institute of microbiology**
- **Moscow State University**

and in last time in

- **Bochvar High-Technology Scientific Research Institute for Inorganic Material (VNIINM , Russia)**

Biophysical reasons and possible physical mechanisms of isotope transmutation in growing biological systems are described in details in numerous articles, two patents and in two books:
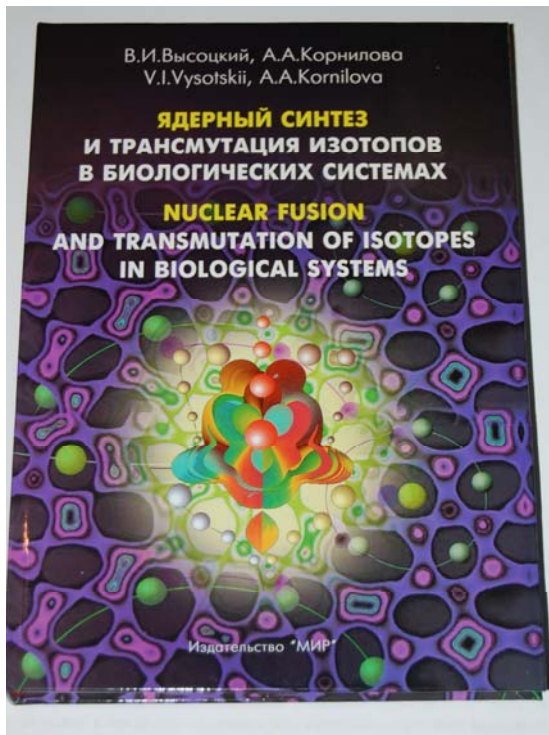
Vysotskii V.I., Kornilova A.A. Nuclear Fusion and transmutation of isotopes in biological systems, **Moscow, MIR Publishing House, Russia, 2003**

Vysotskii V.I., Kornilova A.A. Nuclear transmutation of stable and radioactive isotopes in biological systems, **Pentagon Press, India, Delhi, 2010.**
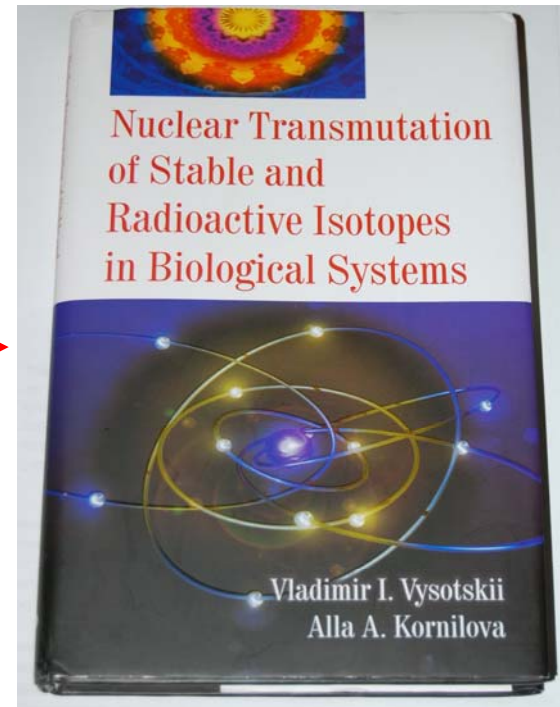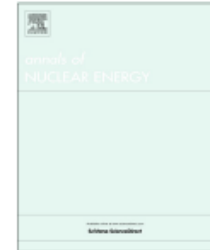
Transmutation of stable isotopes and deactivation of radioactive waste in growing biological systems

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

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[b] Moscov Lomonosov's State University, Moscow 119899, Russia

ARTICLE INFO

ABSTRACT

The report presents the results of qualifying examinations of stable and radioactive isotopes transmutation processes in growing microbiological cultures. It is shown that transmutation of stable isotopes during the process of growth of microbiological cultures, at optimal conditions in microbiological associations, is 20 times more effective than the same transmutation process in the form of "one-line" (pure) microbiological cultures. In the work, the process of direct, controlled decontamination of highly active intermediate lifetime and long-lived reactor isotopes (reactor waste) through the process of growing microbiological associations has been studied. In the control experiment (flask with active water but without microbiological associations), the "usual" law of nuclear decay applies, and the life-time of Cs^{137} isotope was about 30 years.

The most rapidly increasing decay rate, which occurred with a lifetime $\tau^* \approx 310$ days (involving an increase in rate, and decrease in lifetime by a factor of 35 times) was observed in the presence of Ca salt in closed flask with active water contained Cs^{137} solution and optimal microbiological association.

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(12) ABSTRACT OF INVENTION

(54) METHOD FOR PRODUCING STABLE ISOTOPES DUE TO NUCLEAR TRANSMUTATION, SUCH AS LOW-TEMPERATURE NUCLEAR FUSION OF ELEMENTS IN MICROBIOLOGICAL CULTURES

(57) Abstract:
FIELD: nuclear physics. SUBSTANCE: microorganism cells growing in nutrient medium deficient in respect to target isotope (target isotopes) are subjected to action of factors enhancing failure of interatomic binding and causing concentration of free atoms or ions of hydrogen isotopes. Nutrient medium is formed on heavy water base. Nutrient medium is doped with outside isotopes whose reaction results in nonstable isotopes deficient for nutrient medium which decay in the end and form target stable isotopes. Improved speed of formation of stable isotopes. EFFECT: enlarged number and types of isotopes produced. 5 cl

(12) **ABSTRACT OF INVENTION**

(72) Inventor(s):
   Vysotskij Vladimir Ivanovich (UA),
   Kornilova Albina Aleksandrovna (RU)

(73) Proprietor(s):
   Kornilova Albina Aleksandrovna (RU)

RU 2580952

(54) **METHOD OF WATER PURIFICATION FROM RADIONUCLIDES**

(57) Abstract:

FIELD: chemistry.

SUBSTANCE: in claimed method prepared is nutrient medium for growth of microbiological cultures, deficient by chemical element, corresponding to isotope, radionuclides, which do not lead death of biomass due to radioactive irradiation, up to reaching concentration of solution to be purified. Then optimisation of biological part of process of transmutation in obtained

Method for purifying water of radionuclides
WO 2015156698 A1

РЕФЕРАТ

The invention relates to the field of water purification. The present method for purifying water of radionuclides by nuclear transmutation involves preparing a culture medium for the growth of microbiological cultures, adding a biomass of microorganisms to said medium, holding the biomass of microorganisms in an aqueous solution undergoing purification for from 10 hours for aerobic microorganisms to 24 hours for anaerobic microorganisms, and adding key trace elements and/or combinations thereof to different parts of the resultant aqueous solution. The aqueous solution undergoing purification is held for the purpose of selecting the trace elements and/or combinations thereof necessary to speed up the process of transmutation, and the selected trace elements and/or combinations thereof are added to the aqueous solution undergoing purification. The aqueous solution undergoing purification is held for the time necessary to achieve the required residual radioactivity value, and the biomass of microorganisms is removed from the aqueous solution undergoing purification.

THE POSSIBLE THEORETICAL MODEL OF COULOMB BARRIER SUPPRESSION IN DYNAMICAL PHYSICAL AND BIOLOGICAL SYSTEMS

On our opinion the process of isotope transmutation in biological systems occurs according to strict laws of physics, but it is induced by certain features of growing biological objects' structure.
According to this postulate let us consider briefly the possible mechanisms of nuclei interaction that contribute to effective nuclear transmutation reaction $Mn^{55} + d^2$ with the formation of *Fe-57* isotope.
It is evident that tunneling quantum processes can't provide a great probability of nuclear transmutation (e.g. for D_2 molecule the probability of "usual" tunneling dd-fusion is $\lambda_{dd} \approx 10^{-70} s^{-1}$). We would like to note that all relations for the probability of the tunnel effect have been obtained on the basis of the stationary Schrodinger equation and therefore, relate only to stationary interaction of the nuclei, although the process itself is never stationary. Non-stationary nature of any interaction is evident from the fact that a system of interacting nuclei has its own history and has been formed at some point in the past.

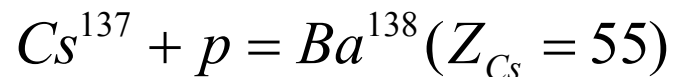# The physical reasons and mechanism of isotope transmutation in biological systems

The problem of nuclear fusion at low energy

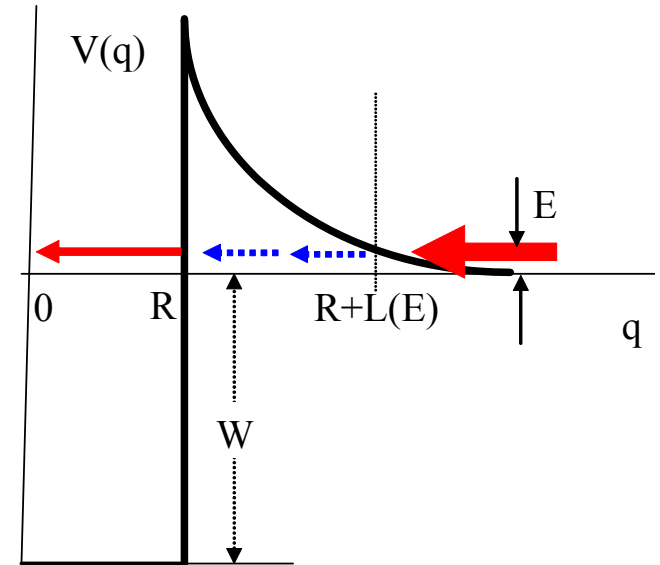$$W(E) = (2/\hbar) \int_R^{R+L(E)} \sqrt{2M[V(q)-E]}\, dq =$$

$$\exp\{-2\pi Z_1 Z_2 /137\beta\},\ \beta = v/c$$

$$D = e^{-W(E)};\quad without\ screening$$

$$V_{max} = Z_1 Z_2 e^2 / R \approx 6\, MeV$$

$$Cs^{137} + p = Ba^{138}(Z_{Cs} = 55)$$

$$T = 300K,\ \overline{v}/c \approx 3.10^{-4},\ Z_1 = 55,\ Z_2 = 1,\ D \approx 10^{-2000}$$

$$D_{r=0} = \exp\left(-2\pi\eta(E_{eff})\right);\, with\ screening$$

$$\eta(E_{eff}) = Z_1 Z_2 e^2 \sqrt{\mu / 2\hbar^2 E_{eff}}\,),$$

$$E_{eff} \approx kT + Z_1 Z_2 e^2 / R_{screen} \equiv kT + E_{screen},\ E_{screen(experiment)} \approx 250\, eV$$

$$D_{r=0}^{(Cs+p)} \approx 10^{-1000}$$

In our works (see below) the most universal mechanism of optimization of low energy nuclear reactions on the basis of correlated states of interacting particles is considered. This mechanism provides giant increase of barrier penetrability under critical conditions (very low energy, high barrier), where the effectiveness of "ordinary" tunneling effects is negligibly small, and can be applied to different experiments.

The physical reason of the barrier penetrability increasing in correlated states is connected with the modified uncertainty relation for correlated states.

It was shown for the first time that in real nuclear-physical systems very sharp grows (**up to** $10^{30}...10^{50}...10^{200}...10^{1000}$ **and more times!**) of Coulomb barrier penetrability at very low energy (e.g. at E≤0.025 eV in partially correlated states of interacting particles is possible. Several successful low-energy correlated-induced fusion experiments are discussed.

THEORETICAL
AND MATHEMATICAL PHYSICS

Correlated States of Interacting Particles and Problems of the Coulomb Barrier Transparency at Low Energies in Nonstationary Systems

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Abstract—Premises for the formation of a correlated coherent state of particles in nonstationary quantum systems are considered. The relation between the correlation factor of particles and the probability of their passage through the potential barrier (including that in nuclear reactions) is analyzed. The optimal regime for parametric excitation of a harmonic oscillator is found, in which the asymptotic formation of the correlated state of particles takes place, the dispersion of their coordinates increases manifold, and the barrier transparency becomes many orders of magnitude higher at a low energy of interacting particles.

INTRODUCTION

It is well known that the tunnel effect plays an extremely important role in atomic and nuclear physics. This effect underlies the operation of most instru...

mately, the total tunneling probability for a superposition of states is the sum of very small values of tunneling probabilities for each of these initial states.

However, for correlated states, the situation is completely different. Mutual synchronization of different...

ФОРМИРОВАНИЕ И ИСПОЛЬЗОВАНИЕ КОГЕРЕНТНЫХ КОРРЕЛИРОВАННЫХ СОСТОЯНИЙ ЗАРЯЖЕННЫХ ЧАСТИЦ В ФИЗИКЕ КАНАЛИРОВАНИЯ В КРИСТАЛЛАХ

© 2010 г.   В. И. Высоцкий[1,2], С. В. Адаменко[1], М. В. Высоцкий[2]

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В работе на примере эффекта каналирования заряженных частиц в кристаллах рассмотрены особенности проявления корреляционных эффектов в квантовых системах. Изучена возможность формирования когерентного коррелированного состояния частиц за счет деформации параболической потенциальной ямы, которая определяет движение заряженных частиц в пространстве между кристаллическими плоскостями при каналировании. Показано, что такая деформация может быть осуществлена при неоднородном (относительно продольной координаты) возбуждении атомов, образующих стенки канала. Путем численного моделирования показано, что каналирование частиц, находящихся в когерентном коррелированном состоянии, приводит к резкому возрастанию вероятности туннельного эффекта и возможности проникновения каналируемых частиц в пространство под барьером.

ВВЕДЕНИЕ

Процесс каналирования заряженных частиц в кристаллических каналах является одной из наиболее успешных реализаций управляемого квантового объекта, сочетающего достоинства квантовой системы с дискретными уровнями энергии и преимущества релятивистских объектов с возможностью очень большого изменения частотно-угловых характеристик

коррелированные состояния (ННС), для которых соотношение неопределенностей, связывающее дисперсии σ_q и σ_p координаты q и одноименной компоненты импульса частицы p имеет вид соотношения Гейзенберга:

$$\sigma_p \sigma_q \geq h^2/4, \quad \sigma_p = \langle (p - \langle p \rangle)^2 \rangle,$$
$$\sigma_- = \langle (a - \langle a \rangle)^2 \rangle. \quad (1)$$

NUCLEI, PARTICLES, FIELDS,
GRAVITATION, AND ASTROPHYSICS

Formation and Application of Correlated States in Nonstationary Systems at Low Energies of Interacting Particles

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Abstract—We consider prerequisites and investigate some optimal methods for the formation of a correlated coherent state of interacting particles in nonstationary systems. We study the influence of the degree of particle correlation on the probability of their passage through the Coulomb barrier for the realization of nuclear reactions at low energies. For such processes, the tunneling probability and, accordingly, the probability of nuclear reactions can grow by many orders of magnitude (in particular, the barrier transparency increases from $D_{r=0} \approx 10^{-42}$ for an uncorrelated state to $D_{|r|=0.98} \approx 0.1$ at a correlation coefficient $|r| \approx 0.98$). The formation of a correlated particle state is considered in detail for different types of monotonic decrease in the frequency of a harmonic oscillator with the particle located in its parabolic field. For the first time, we have considered the peculiarities and investigated the efficiency of the creation of a correlated state under a periodic action on a harmonic oscillator. This method is shown to lead to rapid formation of a strongly correlated particle state that provides an almost complete clearing of the potential barrier even for a narrow range of oscillator frequency variations.

1. INTRODUCTION

The problem of overcoming the Coulomb...

rium or tritium under terrestrial conditions virtually unrealistic [1, 2].

Subbarrier Interaction of Channeling Particles under the Self-Similar Excitation of Correlated States in a Periodically Deformed Crystal

V. I. Vysotskii[a, b], S. V. Adamenko[b], and M. V. Vysotskii[a]

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Abstract—It has been shown that application of the periodic modulation of parabolic potential well parameters (in the case of charged particle channeling in crystals, i.e., periodic spatial modulation of the wall height of a potential well in the crystal channel) leads to the formation of the coherent channeling state in particles in this well. The formation of this state changes the interaction process between these particles and nuclei, and increases the barrier transparency by many times. For channeling this mode can be formed using, e.g., the longitudinal acoustic wave running along the channel axis. This wave changes the distance between nuclei and, accordingly, modulates the height of channel walls.

INTRODUCTION

Conventional studies of particle channeling...

which differs from the "standard" Heisenberg uncer...

Acceleration of low energy nuclear reactions by formation of correlated states of interacting particles in dynamical systems

Vladimir I. Vysotskii [a,*], Stanislav V. Adamenko [b], Mykhaylo V. Vysotskyy [a]

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ARTICLE INFO

ABSTRACT

In this work the most universal mechanism of essential acceleration of low energy nuclear reactions on the basis of correlated states of interacting particles is considered. This mechanism provides a giant increase of barrier penetrability under critical conditions (low energy, high barrier), where the effectiveness of "ordinary" tunneling effects is negligibly small, and can be applied to different experiments. The physical reason of an increased barrier penetrability in correlated states is connected to the modified uncertainty relation $\sigma_p \sigma_q \geqslant \hbar^2/4\left(1 - r_{pq}^2\right)$ for correlated states and to the increase in momentum σ_p and position σ_q variances with increasing of correlation coefficient r_{pq}. We have considered preconditions and methods of formation of correlated coherent states of interacting nuclei in non-stationary dynamical systems. It was shown that in real nuclear-physical systems at $r_{pq}^2 \rightarrow 1$ very sharp growth (up to a factor of 10^{30}–10^{100} and more!) of Coulomb barrier penetrability at very low energy of interacting particles is possible. Several successful low-energy correlated-induced fusion experiments are discussed.

Regular Article – Theoretical Physics

Coherent correlated states and low-energy nuclear reactions in non stationary systems

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Kiev National Shevchenko University, Kiev, Ukraine

Abstract. In this paper the universal mechanism of optimization of low-energy nuclear reactions on the basis of coherent correlated states of interacting particles is discussed. The formation of these states is the result of the special nonstationary low-energy action to any one of these interacting particles. We have considered the peculiarities and investigated the efficiency of the creation of a correlated state under monotonous or periodic action on the particle that is situated in the parabolic potential. This method is shown to lead to the rapid formation of a strongly correlated particle state that provides an almost complete clearing of the potential barrier even for a narrow range of oscillator frequency variations. The successful low-energy fusion experiment based on the use of correlated states of interacting particles at laser irradiation is discussed.

1 Introduction

Together with these "classical" and extremely expen-

The possible mechanism of LENR is connected with formation of coherent correlated states of interacting nuclei in nonstationary potential wells in GROWING BIOLOGICAL SYSTEM.

It was shown in our works that a certain non-stationary deformation of potential well in which even one of the interacting particles is located leads to a significant increase in nuclear barrier transparency. Such effect is due to the formation of **coherent correlated states (CCS)** of a particle featuring the synchronization effect and the efficient summation (interference) of fluctuations of different components of particle's momentum in a non-stationary superpositional state. Said summation generates large final fluctuations of total momentum and fluctuations of particle's kinetic energy, which contributes to a significant increase in potential barrier's transparency factor and hence to similar increase in the probability of nuclear fusion reaction.

Uncorrelated state   **Correlated state**   *A simple interpretation of the process of formation of giant fluctuations of total momentum and particle's kinetic energy*

$\Delta \vec{p}_{n+1}$ $\Delta \vec{p}_{n+1}$

$\Delta \vec{p}_n$ $\Delta \vec{p}_n$

$\Delta \vec{p}_{n-1}$ $\Delta \vec{p}_{n-1}$
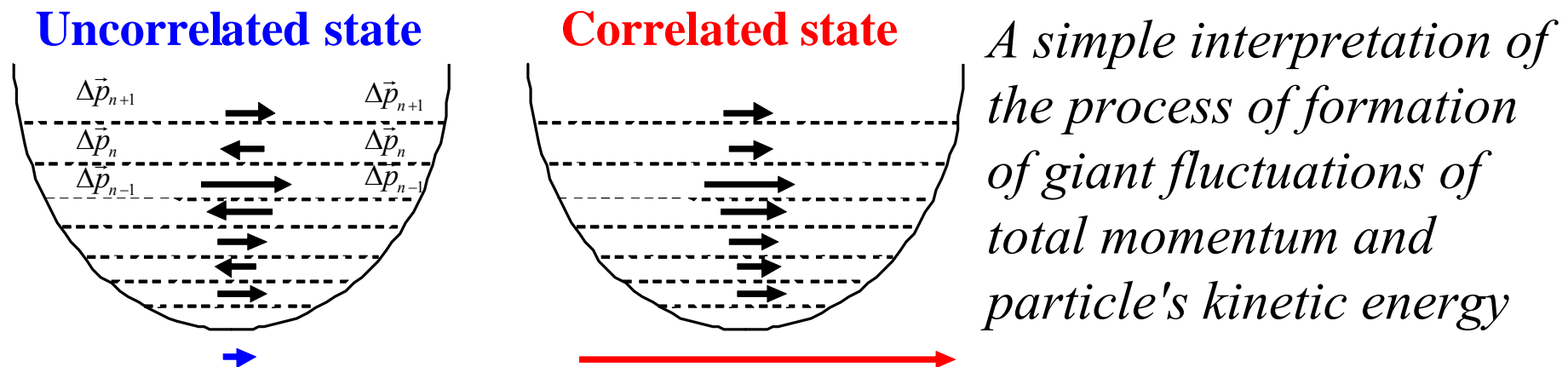
Correlated coherent states of particles and Schrödinger-Robertson uncertainty relation

In 1930, Schrödinger and Robertson independently generalized the Heisenberg idea of the quantum-mechanical uncertainty of different dynamical quantities A and B on the basis of the more correct analysis of base expression

$$G = \int_{-\infty}^{\infty} |\alpha u(q) + iv(q)|^2 \, dq \geq 0$$

$$u = \Delta\hat{A}\psi(q) \equiv (\hat{A} - <A>)\psi(q) \qquad v = \Delta\hat{B}\psi(q) \equiv (\hat{B} - <B>)\psi(q)$$

If we remove the ungrounded limitation that the parameter α is purely real, then yields the more universal condition called the Schrödinger--Robertson uncertainty relation.

$$\sigma_A \sigma_B \geq \frac{|<[\hat{A}\hat{B}]>|}{4(1-r^2)}; \quad r = \sigma_{AB} / \sqrt{\sigma_A \sigma_B}$$

$$-1 \leq r \leq 1$$

- coefficient of cross correlation

$$\sigma_{AB} = \frac{<\{\Delta\hat{A}, \Delta\hat{B}\}>}{2} = \frac{(<\hat{A}\hat{B}> + <\hat{B}\hat{A}>)}{2} - <A><B>$$

cross dispersion of A and B

From Schrödinger--Robertson uncertainty relation follows

$$\delta p \delta q \geq \frac{\hbar}{2\sqrt{1-r^2}} \equiv \frac{\hbar_{eff}}{2};$$

$$\delta E \delta t \geq \frac{\hbar_{eff}}{2}, \qquad \hbar_{eff} = \frac{\hbar}{\sqrt{1-r^2}}$$

At $\quad |r| \longrightarrow 1$ we have $\quad \delta p \delta q \to \infty, \ \hbar_{eff} \to \infty$

and $\qquad\qquad\qquad \delta p \to \infty, \ \ \delta q \to \infty$

$$\delta p \, \delta q \geq \frac{\hbar}{2\sqrt{1-r^2}} \equiv \frac{\hbar_{eff}}{2} - \text{ Schrödinger--Robertson uncertainty relation}$$

$$r = \frac{\{<qp> + <pq>\}}{2\sqrt{<p^2><q^2>}};$$

$$\delta E \, \delta t \geq \frac{\hbar_{eff}}{2}, \qquad \hbar_{eff} = \frac{\hbar}{\sqrt{1-r^2}} -$$

For Coulomb potential barrier the modified uncertainty relation is

$$\delta q \geq \frac{\hbar}{2\sqrt{1-r^2}\,\delta p} \equiv \frac{\hbar_{eff}}{2\delta p} = \frac{\hbar}{2\sqrt{1-r^2}\,\sqrt{8M}\,<\sqrt{V(q)-E}>}\Bigg|_{|r|\to 1} \Big| \to \infty$$
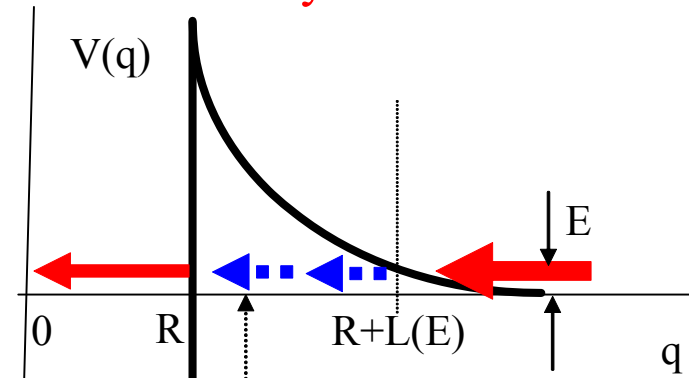
At full correlation |r|→1 the mean square effective coordinate of a particle will be unlimited (δ→∝) at any energy!
In this ideal case the tunnel transparency of arbitrary potential barrier will be close to 1 at any low energy E of the particle (!):

$$D_r = e^{-W(E)} \approx e^{-\sqrt{1-r^2}\,L(E)/\delta q} = (D_{r=0})^{\sqrt{1-r^2}} \to 1 \; at \; |r| \to 1$$

It has been shown in our work

[V. I. Vysotskii, M.V.Vysotskyy. Correlated States and Transparency of a Barrier for Low-Energy Particles at Monotonic Deformation of a Potential Well with Dissipation and a Stochastic Force. Journal of Experimental and Theoretical Physics, 2014, Vol. 118, No. 4, pp. 534–549]

that at monotonic deformation (expansion or compression) a potential well a correlated coherent state is rapidly formed with a large correlation coefficient |r|>0.999…0.999999, which corresponds at a low energy of the particle E≈kT to a very significant (by a factor of $10^{50}…10^{500}$ or larger) increase of very low barrier transparency

$$D_{noncorr} \approx 10^{-100}...10^{-1000}$$

at its interaction with atoms (nuclei) forming the "walls" of the potential well or other atoms located in the same well up to

$$D_{corr} \rightarrow 1$$

Formation of correlated states at monotonous deformation of potential well

A.Monotonously limited increasing potential well $(L_0 \to L_{max})$
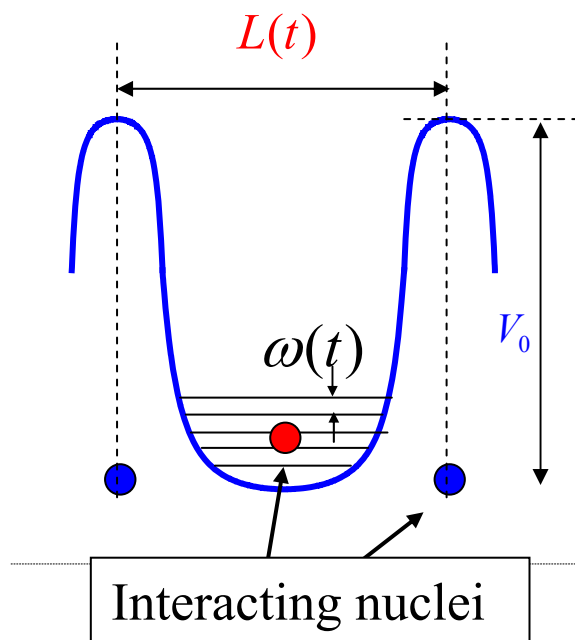
$L(t) = L_0(g+1)/(g+e^{-t/T}) - \text{width of crack};$

$T - duration\ of\ growth\ of\ crack$

$L_{max}/L_{min} = (g+1)/g \approx 1/g, \ g = (L_{max}/L_o - 1), g \ll 1$

$\omega(t) = \omega_0(g+e^{-t/T})/(g+1)$

$L(t)$

$\omega(t)$

V_0

Interacting nuclei
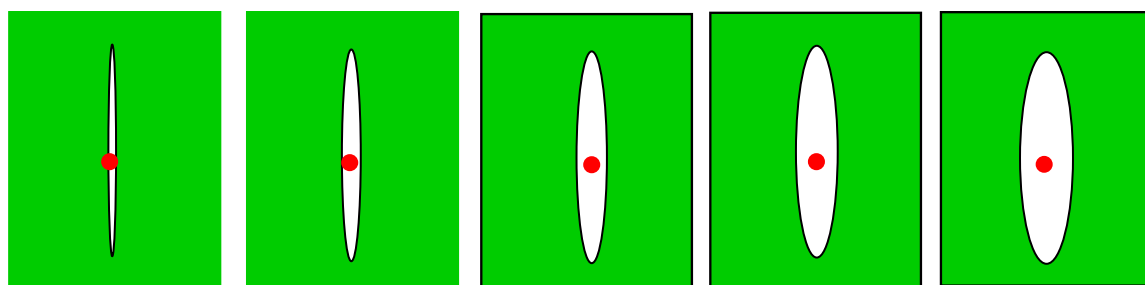
$t_1 \quad < \quad t_2 \quad < \quad t_3 \quad < \quad t_4 \quad < \quad t_5$

The evolution of the internal local nanocavities in the growing biological structure
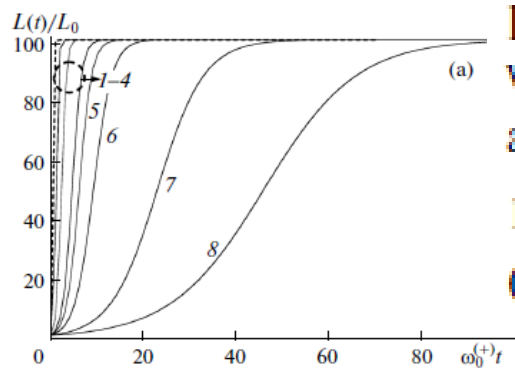
Fig. 3. Time dependences of (a) the width of the potential well and the correlation coefficient in the (b) linear scale and (c) logarithmic scale in the expanding well at $g^{(+)} = 100$ ($L_{max}/L_0 = 101$) and $T\omega_0^{(+)} = $ (1) 0.1, (2) 0.25, (3) 0.5, (4) 1.0, (5) 1.33, (6) 2, (7) 5, and (8) 10.
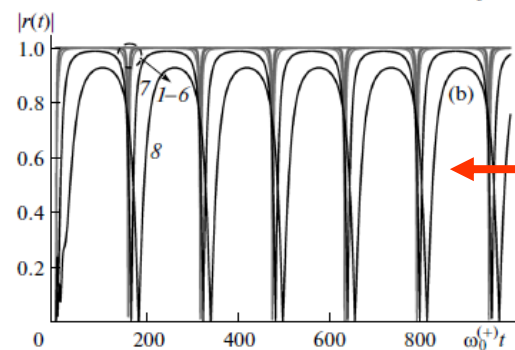
$$Cs^{133} + p = Ba^{134}$$

$$L_{max} / L_0 \approx 100, L_0 = 2A, L_{max} = 200A$$

$$r = 0; D_{Cs+p}(E = 0.25eV, r = 0) \leq 10^{-1000}$$

$$r_{max} \approx 0.9999; D_{Cs+p}(E = 0.25eV, r_{max}) \approx 10^{-14};$$

$$L_{max} / L_0 \approx 10^3, L_0 = 2A, L_{max} = 2000A$$
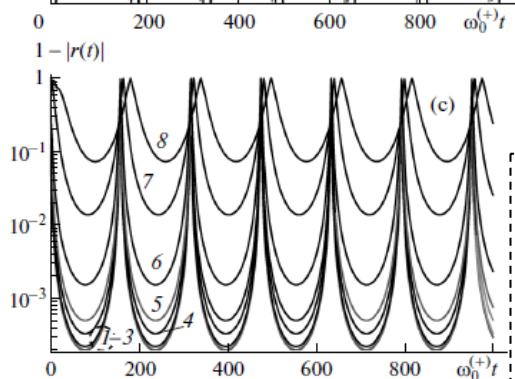
$$r_{max} \approx 0.999999; D_{Cs+p}(E = 0.25eV, r_{max}) \approx 0.04!$$

V. I. Vysotskii, M.V.Vysotskyy. Correlated States and Transparency of a Barrier for Low-Energy Particles at Monotonic Deformation of a Potential Well with Dissipation and a Stochastic Force. *Journal of Experimental and Theoretical Physics, 2014, Vol. 118, No. 4, pp. 534–549*

Fig. 4. Time dependences of the correlation coefficient in the wide expansion interval of the potential well at $g^{(+)} \approx L_{max}/L_0 = $ (a) 10^3, (b) 10^4, and (c) 10^5, and $T\omega_0^{(+)} = $ (1) 0.1, (2) 0.25, (3) 0.5, (4) 1.0, (5) 1.33, (6) 2, (7) 5, and (8) 10.
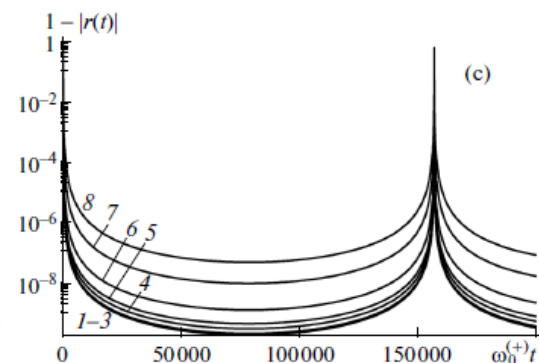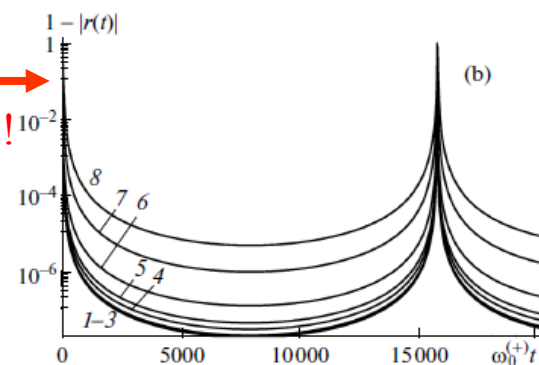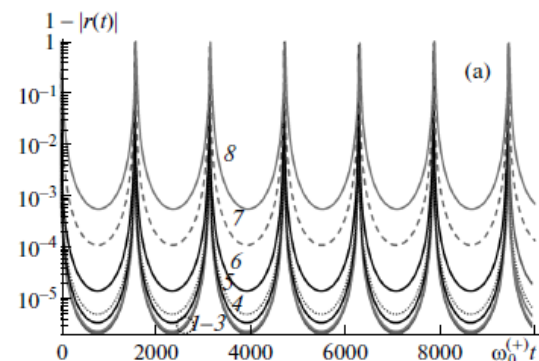
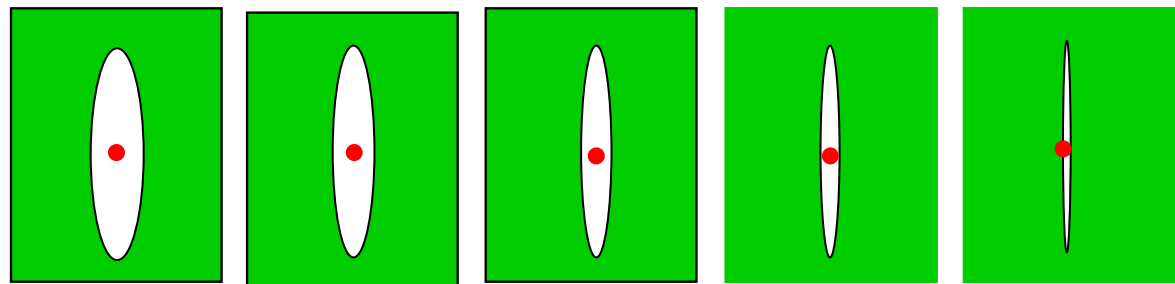# B. Limited decreasing potential well $L_{max} \to L_0$
(e.g. "crack healing" in nano-physical systems and natural biological systems)
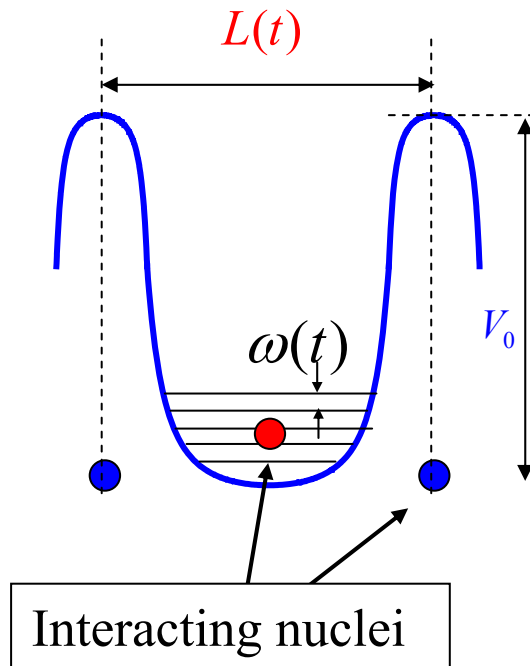
$$L(t) = L_0(g + e^{-t/T}) / (g + 1) - \text{width of crack};$$

$$\omega(t) = \omega_0(g + 1) / (g + e^{-t/T})$$
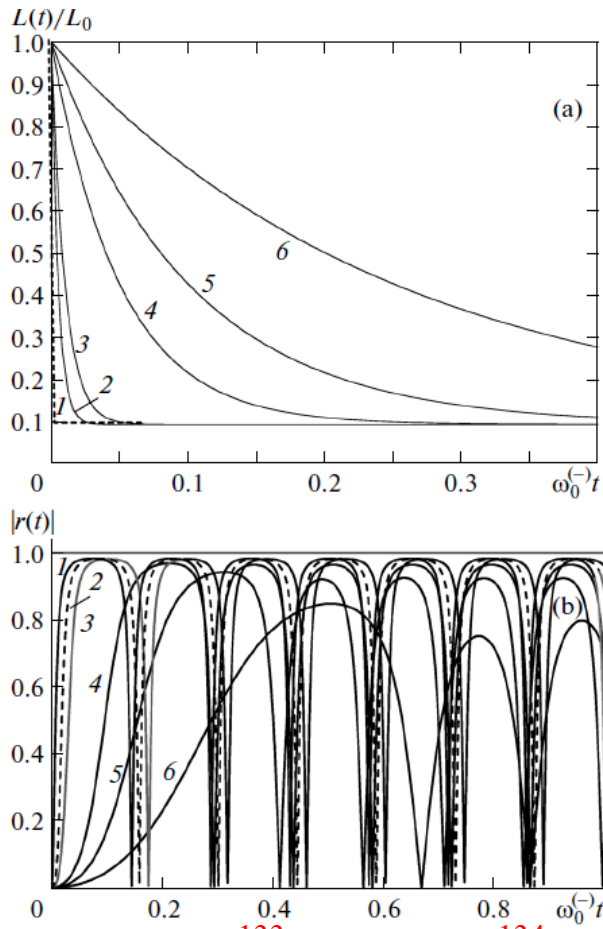
$$L : L_{max} = L_0, \ L_{min} \equiv L_0 / (1 + g)$$

Interacting nuclei

$$t_1 \ < \ t_2 \ < \ t_3 \ < \ t_4 \ < \ t_5$$

Fig. 5. Time dependences of (a) the width of the contracting potential well and (b) the correlation coefficient at $g^{(-)} = 10$, $L_0/L_{max} = 11$, and $T\omega_0^{(-)} = $ (*1*) 0.001, (*2*) 0.005, (*3*) 0.01, (*4*) 0.05, (*5*) 0.1, and (*6*) 0.25.

Fig. 6. Time dependences of the correlation coefficient in the wide contraction interval of the potential well at $g^{(-)} \approx$

$$L_0/L_{min} = \text{(a) } 10^2 \text{ and (b) } 10^3 \text{ and } T\omega_0^{(-)} = \text{(*1*) 0.001,}$$

(*2*) 0.005, (*3*) 0.01, (*4*) 0.05, (*5*) 0.1, and (*6*) 0.25.
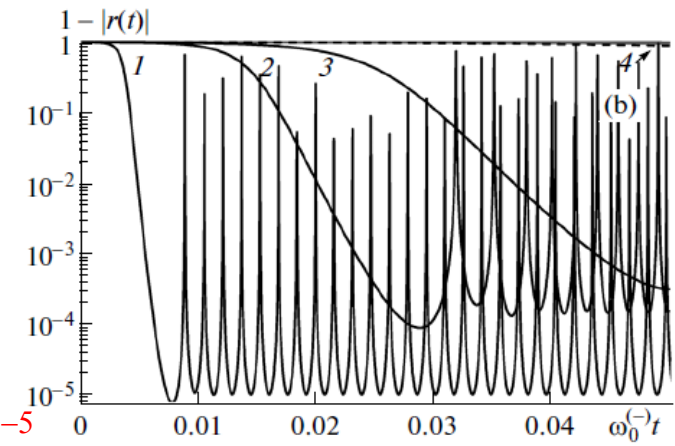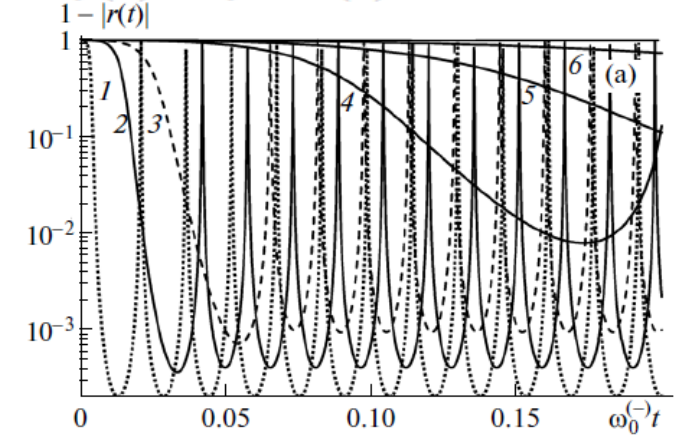
$$Cs^{133} + p = Ba^{134}$$
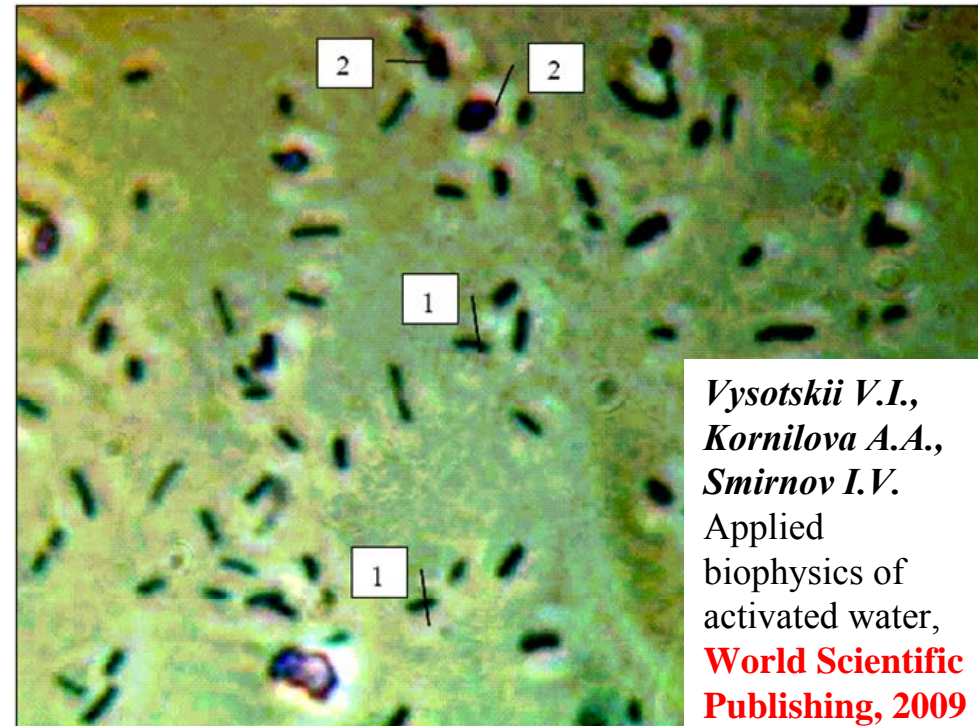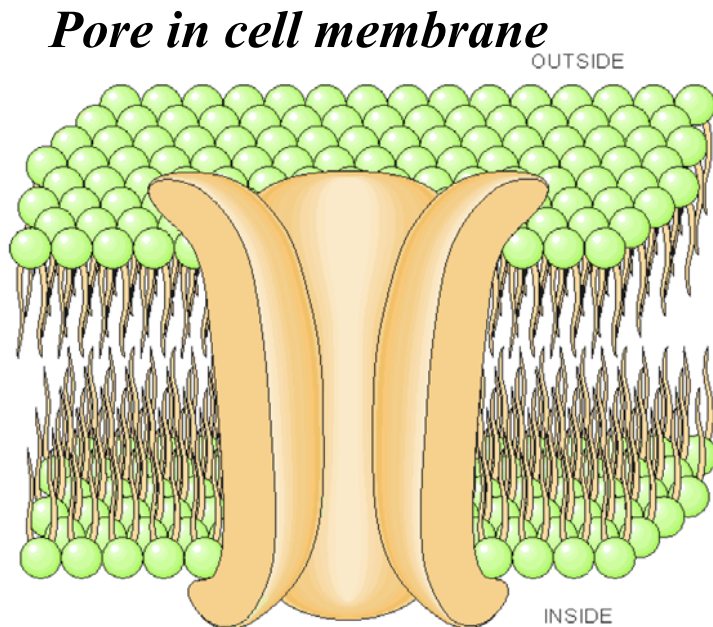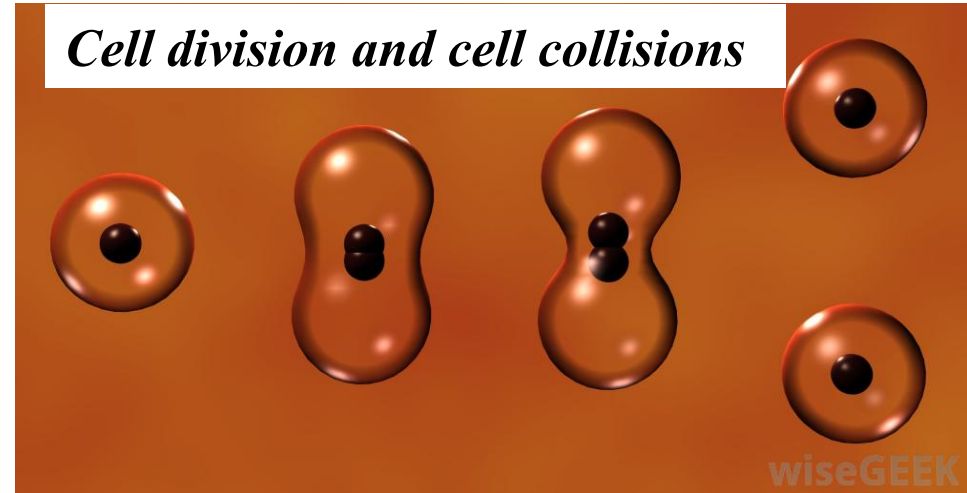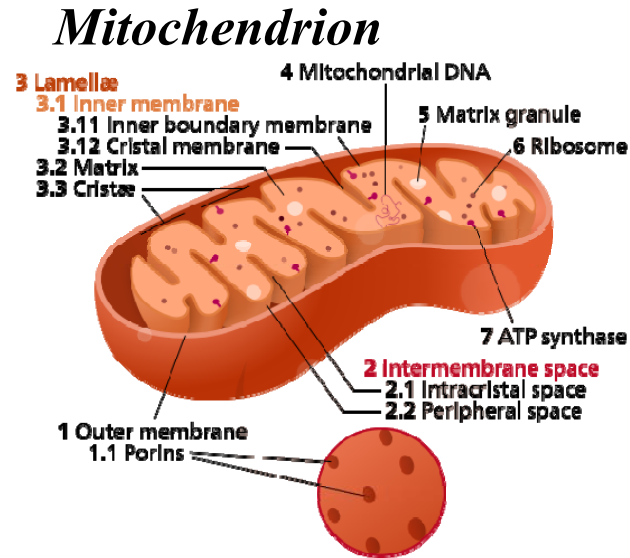
$$L_0 / L_{min} \approx 100, L_0 = 200A, L_{min} = 2A$$

$$r=0; D_{Cs+p}(E = 0.25eV, r=0) \leq 10^{-1000}$$

$$r_{max} \approx 0.9999; D_{Cs+p}(E = 0.25eV, r_{max}) \approx 10^{-14};$$

$$L_0 / L_{min} \approx 10^3, L_0 = 2000A, L_{min} = 2A$$

$$r_{max} \approx 0.99999; D_{Cs+p}(E = 0.25eV, r_{max}) \approx 3*10^{-5}$$

Formation of non-stationary potential wells in growing biological objects (the possible place of CCS formation and LENR realization)

Mitochendrion

3 Lamellae
3.1 Inner membrane
3.11 Inner boundary membrane
3.12 Cristal membrane
3.2 Matrix
3.3 Cristae

4 Mitochondrial DNA
5 Matrix granule
6 Ribosome
7 ATP synthase

2 Intermembrane space
2.1 Intracristal space
2.2 Peripheral space

1 Outer membrane
1.1 Porins

Pore in cell membrane

OUTSIDE

INSIDE

Cell division and cell collisions

wiseGEEK

Vysotskii V.I., Kornilova A.A., Smirnov I.V. Applied biophysics of activated water, **World Scientific Publishing, 2009**
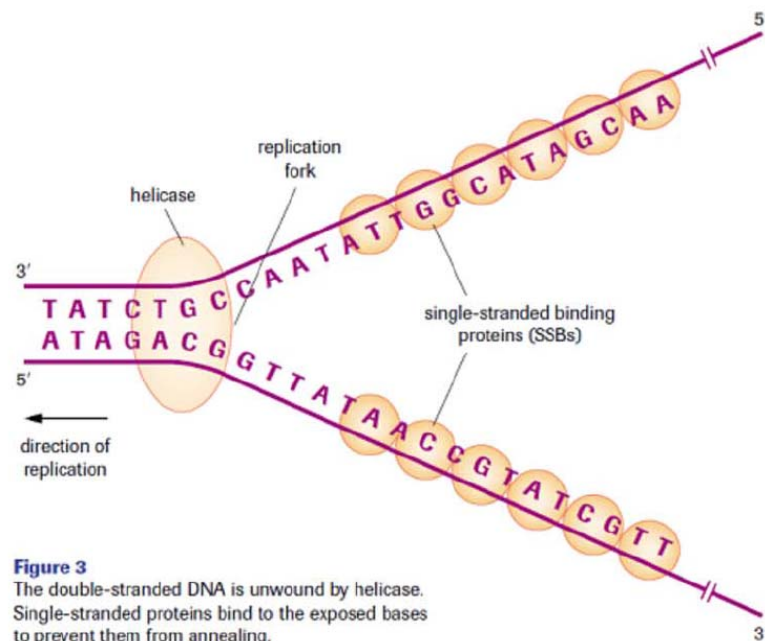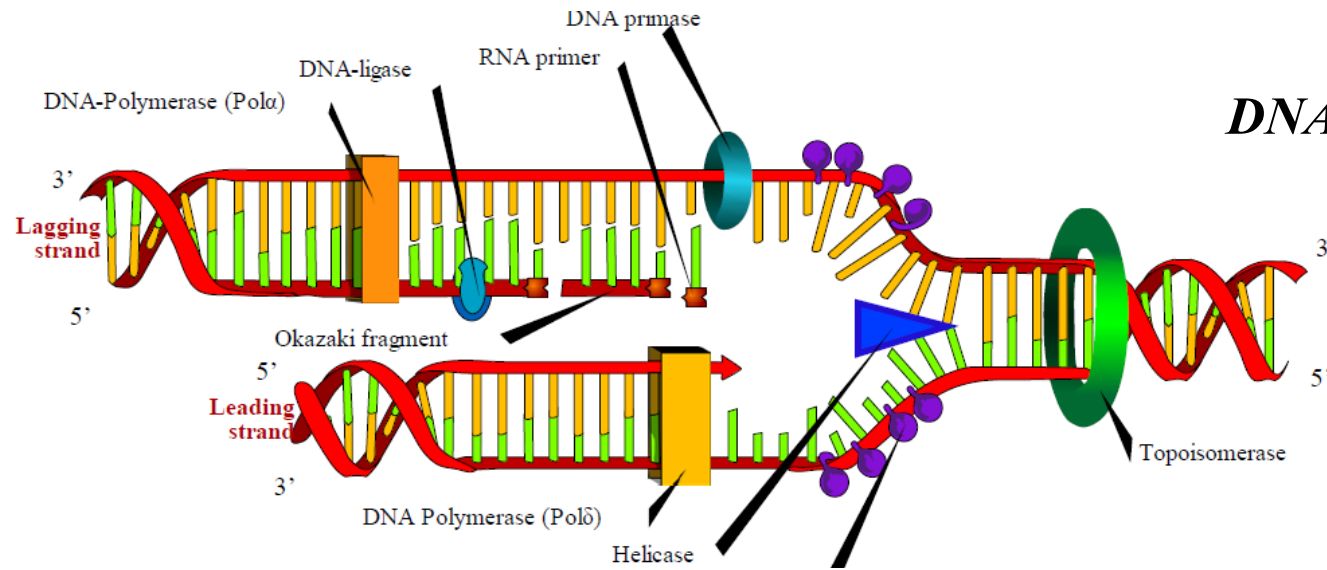
DNA replication

Figure 3
The double-stranded DNA is unwound by helicase.
Single-stranded proteins bind to the exposed bases
to prevent them from annealing.

Formation of nonstationary "replication bubbles" (nonstationary potential wells) at DNA replication
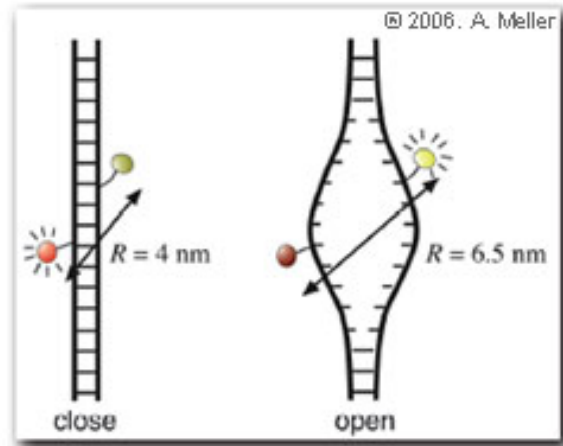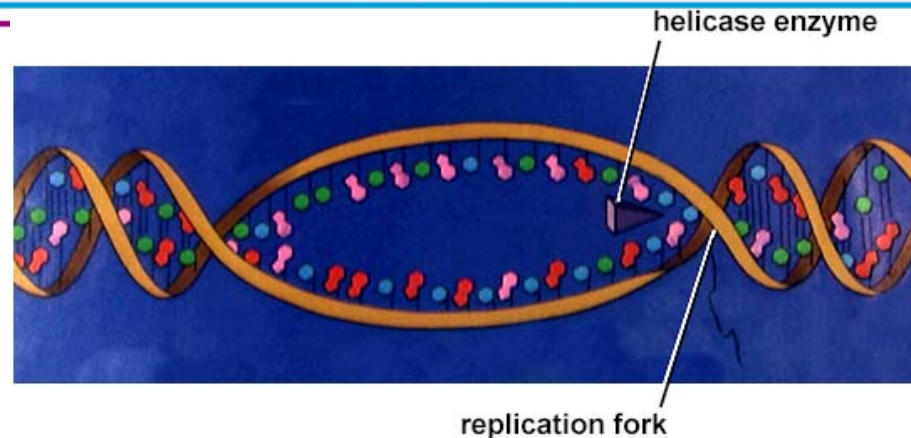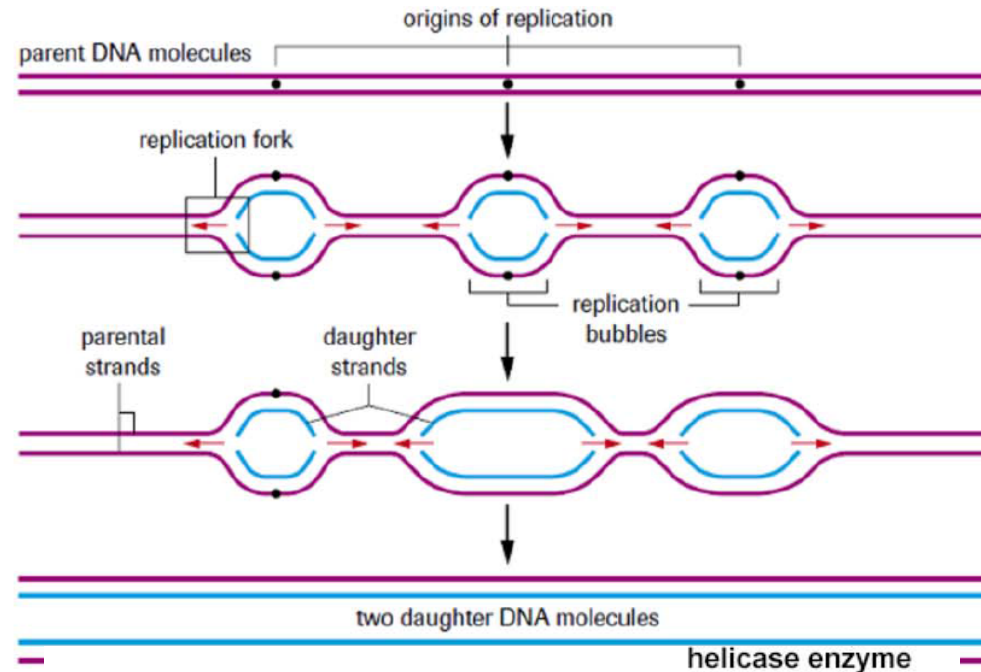
Image showing DNA replication in Prokaryotes

3. Another enzyme gyrase helps to release the tension in the separated strands by cutting and resealing them.

4. DNA is unwound at multiple locations forming bubbles known as replication bubbles. The junction where DNA is still attached is known as replication fork.

Conclusions

The presented results show perspectives of use of the effect of stable and radioactive isotopes transmutation in biological systems for natural and industrial applications.

Presented results clearly demonstrate the "giant" increases (by many order of magnitude) of localization density under the potential barrier and also the possibility of very effective under the barrier penetrations of particles at the increase of correlation coefficient (up to $10^{100}...10^{1000}$ and more times).

Such effects possible take place in different nonstationary LENR experiments with release of energy (including experiments on isotopes transmutation in growing microbiological systems).

These results can give the answer to the question of the reasons of abnormal accelerated decrease of environmental radioactivity in some isolated areas inside Chernobyl accident zone with initial high level of radiation pollution.

- In conducted experiments the decrease in the concentration of radioactive reactor Cs^{137} isotope by 23% (average value) and up to 40-70% (in the most optimal bioreactors) during 7-10 days was observed due to its transmutation into a stable isotope of barium

- For further stages (up to 100%) of Cs^{137} isotope transmutation it is necessary to make the operational changes to the composition of the nutrient medium during transmutation.

- The presented results show perspectives and effectiveness of radioactive Cs^{137} isotope deactivation and radioactive water purification during controlled growth of microbiological syntrophic association for industrial and environmental applications (e.g. for accelerated deactivation of radioactive water in Fukushima area).

- The results of an independent examination confirmed the correctness of our previous results on the deactivation of radioactive isotopes, previously conducted at the "Shelter" object in Chernobyl
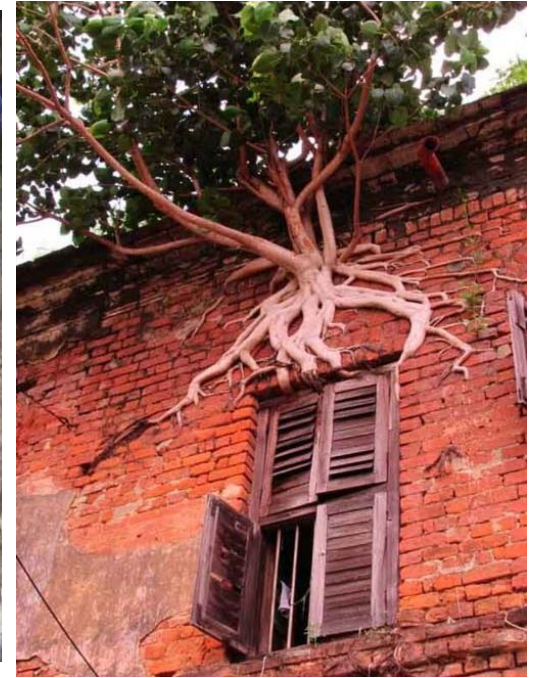
Illustration of fantastic adaptation of biology systems to aggressive and nonoptimal environment