A Microbiological method for the transmutation of chemical elements and isotopes of chemical elements transformations.

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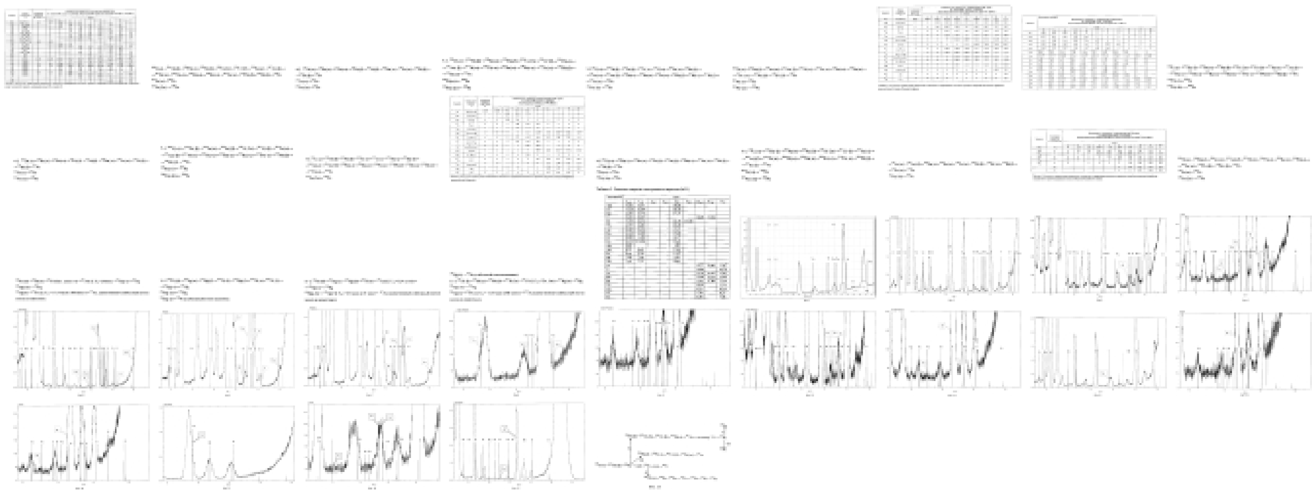
$$^{230}\mathrm{Th}(n, \gamma) \rightarrow {}^{231}\mathrm{Th}\ (\beta^{-}\text{-распад},\ T_{1/2} = 25.6\ \text{ч}) \rightarrow {}^{231}\mathrm{Pa}$$



G21G7 / 00 - Conversion of chemical elements;sources of radioactivity (the use of radiation in general G21H 5/00; control of elementary particles, eg neutrons, or electromagnetic radiation, not provided for in other subclasses, G21K)
G21F9 / 04 - Treatment of liquid radioactive waste
C22B60 / 00 - Preparation of metal with an atomic weight of 87 or higher, i.e. radioactive metals
C22B3 / 18 - with the addition of enzymes or microorganisms, such as bacteria or algae
C12N1 / 20 - Bacteria; Culture media therefor

The invention relates to the field of biotechnology and chemical transmutation. Radioactive feedstock containing radioactive chemical elements or isotopes, treated with an aqueous suspension of bacteria of the genus Thiobacillus, in the presence of variable valence elements. As the use of radioactive materials or ore radioactive waste nuclear fuel cycle.

The process leads to obtaining polonium, radon, France, radium, actinium, thorium, protactinium, uranium, neptunium, americium, nickel, manganese, bromine, hafnium, ytterbium, mercury, gold, platinum, and their isotopes.

The invention allows to obtain valuable radioactive elements, to carry out the inactivation of nuclear waste from the conversion of waste radioactive isotopes of elements into stable isotopes. 2 ZP f-ly, 18 ill., 5 tab., 9 pr.

The invention relates to chemical transmutation of radioactive isotopes and transformation, that is to artificially produce some chemical elements from other elements. In particular, the method allows to obtain rare and valuable elements: polonium, radon, francium, radium, and actinides - actinium, thorium, protactinium, uranium, neptunium, and various isotopes of these and other elements.

Known transformation of chemical elements, the formation of new isotopes of elements and new chemical elements during nuclear fission and synthesis of chemical elements used in conventional nuclear rectors, in nuclear power plants (NPPs) in research nuclear reactors, for example, by irradiation of the chemical elements with neutrons or protons, or alpha particles.

A method of obtaining the radionuclide nickel-63 in the reactor from a target comprising obtaining enriched Nickel-62 nickel target, the irradiation target in the reactor, followed by enrichment of irradiated product from nickel-63 at extraction of nickel-64 isotope product (RU 2313149, 2007).

The advantage of the method is to obtain a high quality product which is designed for use in stand-alone sources of electrical energy, in the detectors of explosives and so on. The reproducibility of the results was confirmed by the analysis of the isotopic composition of elements by mass spectrometry. However, the method is complicated and unsafe degree requires industrial safety.

It is also known the transmutation of elements - long-lived radioactive nuclides, including those arising in irradiated nuclear fuel (RU 2415486, 2011). The method consists in irradiating neutron flux transmutable material, the irradiation is carried out with neutrons obtained in the nuclear fusion reactions in the pre-formed neutron source plasma, at a certain placement of the scattering medium neutrons. This method is based on the reactions of nuclear fusion in a tokamak is also complex and requires special equipment.

A method of obtaining radionuclides Th-228 and Ra-224, which is also implemented in a reactor technology. The technology is quite complex and has a safety limit (RU 2317607, 2008).

Thus, upon receipt of the chemical elements and their isotopes, in general, are conventionally used nuclear reactions involving nuclear reactors or other sophisticated equipment at high energy costs. Attempts have been made to solve the problem of obtaining radioactive isotopes in the process of nuclear transmutation of elements more secure manner using the microorganisms.

Known in particular isotopes conversion method using microorganisms comprising growing microbial culture Deinococcus radiodurans on a nutrient medium containing the necessary for transmutation of initial isotopic components, and deficient close chemical analogues of the target element.

The composition of the medium is introduced, such starting isotopic components which are radioactive and transmutation process can lead to the formation of the target chemical element in the form of a stable or radioactive isotope, which is absorbed by the microbial culture and then remains steady or remains radioactive or decomposed to the desired stable isotope (RU 2002101281 A, 2003). This method does not provide a high yield of the desired isotope, and also requires the use of ionizing radiation as a trigger and response factor supports.

Also known process for the preparation of stable isotopes by nuclear transmutation type of cold fusion elements in microbial cultures (RU 2052223, 1996). The method consists in the fact that the cells of microorganisms are grown in a culture medium deficient isotope target (target isotopes) impact factors contributing to the destruction of the interatomic bonds and leading to an increase in its concentration of free atoms or ions of hydrogen isotopes.

The medium is prepared on the basis of heavy water and injected into it scarce for the environment unstable isotopes that decay at the end to form the desired stable isotopes. As a factor that destroys the interatomic bonds using ionizing radiation. This method is based on the use of ionizing radiation, it is not designed for commercial scale requires a high energy and cost.

All of the chemical elements and their isotopes and by-products obtained until now complex and unsafe traditional methods by conventional nuclear reactions in small (sometimes - in micro) amounts clearly insufficient for the energy, industrial, industrial, technical and scientific needs of mankind.

Described microbial process for the transmutation of chemical elements allows you to receive all of these chemical elements and their isotopes in almost unlimited quantities, simple to perform, safe for workers and the public, environmentally friendly way that does not require large material flow rates, heat, electricity and heating, while providing this energy, industrial, technical and scientific problems of civilization. These elements and isotopes are enormous reserves of energy, have an extremely high value and selling price on the market.

Microbiological method is proposed transmutation of the chemical elements and isotopes of chemical conversion elements, characterized in that the radioactive feedstock containing radioactive chemical elements or isotopes, treated with an aqueous suspension of bacteria of the genus Thiobacillus, in the presence of any s, p, d, f-elements with variable valency.

Selection of elements with variable valence based on the principle of creating a high redox potential. That is, this selection key, or simply on the orientation of these or other elements of variable valency brought into the reaction medium, a redox potential value which is optimal in the range of 400-800 mV (for example, in Examples 1, 2, 3, 4 Eh = 635 mV, 798 mV, 753 mV and 717 mV, respectively).

Items with variable valence, as in the reduced and oxidized forms, creating a standard redox potential, involved in a start-up and control mechanisms of initiation and acceleration of alpha, beta minus and beta plus decay of radioactive isotopes of elements any kind of group of bacteria Thiobacillus.

The method leads to the production of polonium, radon, France, radium, actinium, thorium, protactinium, uranium, neptunium, americium and their isotopes as well as nickel, manganese, bromine, hafnium, ytterbium, mercury, gold, platinum, and their isotopes. As radioactive materials containing radioactive chemical elements can be used ore or radioactive nuclear waste cycles.

According to the inventive method are derived from raw materials containing natural uranium-238 and thorium-232, the following elements:
1. Protactinium, actinides, radium isotopes of polonium and various data elements (Tables 1, 2, 3, 4, scheme 1, 2, 3, 4, 5, 6, 7; figures from 1 to 17).
2. France (Figures 4, 5, 6, 7, 9, 14).
3. Ytterbium, hafnium, gallium, nickel (Table 1; Figures 2, 3, 4, 5, 6, 7), gold (table 1; figure 6, 7), mercury (Tables 1, 2, scheme 9, 10; figures 4, 5, 11), platinum (table 1; scheme 9, 10; figure 4, 5, 6, 7).
4. The iron content in the medium is decreased, there is a nickel (in the original ore had no nickel) and nickel content is increased over time (Table 1) as well as iron assumes alpha particles carried bacterial alpha-radioactive elements, becoming nickel. Separation of the proton nuclei of iron leads to increased manganese content in the medium (in the conversion of iron manganese) and, consequently, to reduce the iron content (Table 1).
5. From polonium, a product of microbiological decay actinides transmutation process elements are obtained various isotopes of thallium, mercury, gold, platinum, including stable (Tables 1, 2, scheme 10, 11; Tables 1 and 2; Figures 1, 2, 3, 4, 5, 6, 7, 11).
6. From the obtained rare isotopes of plutonium-239: uranium-235, thorium-231, protactinium-231, Actinium-227 (Scheme 12).
7. Because of plutonium-241, which is a by-product of the combustion of uranium in the reactor, obtained rare in nature and industry, and deficient isotopes of americium and neptunium ^{241} Am and ^{237} Np (Scheme 13).

Thus, the described microbial process solves the problem of providing energy and scarce rare materials of various fields of industry, science and technology.

Previously, all of these elements and their different isotopes were produced artificially in small and micro-quantities (grams, milligrams, micrograms or less) in nuclear reactions and processes in a nuclear reactor as decay products of uranium and thorium, and plutonium, radium . Artificially in nuclear reactions isotopes of thorium and uranium have also been obtained. The authors obtained in this manner the following elements: polonium, radon, francium, radium, and actinides - actinium, thorium, protactinium, uranium, neptunium, plutonium, americium, and various isotopes of these elements, as well as various isotopes of thorium and uranium - thorium-227, thorium 228, thorium-230, thorium-234; uranium-231, uranium-232, uranium-233, uranium-234, uranium-235, uranium-236, uranium-239, as well as manganese, nickel, gallium, bromo, hafnium, ytterbium, thallium, mercury, gold, platinum (cm. schemes 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, and 13 of table 1, 2, 3, 4).

The claimed method of transmutation of chemical elements allows you to receive all of these chemical elements and their isotopes in virtually unlimited quantities.

The described method of transmutation of elements can also inactivate and neutralize nuclear waste, for example, the combustion of nuclear fuel waste (uranium) from the nuclear power plant, containing uranium, plutonium, and their isotopes and fission decay products (isotopic transitions products): isotopes of uranium and plutonium (see diagram. 13), radium and polonium, radioactive isotopes of strontium, iodine, cesium, radon, xenon and other products alpha and beta decay, and spontaneous fission of uranium and plutonium.

It should be noted that certain traditional nuclear reactor methods for making and isolating polonium, radium, actinium, protactinium, neptunium, americium, and their isotopes and of isotopes of thorium and uranium technologically difficult to carry out, are expensive, require complex and expensive equipment and are dangerous to human health and the environment environment, in contrast to the claimed method. Also known conventional nuclear reactor methods for making and isolating polonium, radium, actinium, protactinium, neptunium, americium, and their isotopes of thorium and uranium isotopes do not provide energy needs and other various fields of science and technology in the data of chemical elements and their isotopes.

The claimed method bacteria of the genus Thiobacillus (eg, species Thiobacillus aquaesulis or Thiobacillus ferrooxidans) in the presence of elements with variable valence, initiate and accelerate the natural processes of decay of the radioactive isotope and radioactive transition elements. At the same time, the natural nuclear reactions and isotopic transitions accelerated in thousands, millions and billions of times - depending on the source of the natural half-life of the isotopes of certain chemical elements.

The feedstock used and any raw material containing radioactive elements, namely:

1. Natural uranium and thorium in the form of ores of uranium and / or thorium ores or sand, for example, monazite sand containing thorium phosphates / phosphates; any ore containing impurities thorium, uranium, plutonium in any amounts and ratios to one another.
2. Plutonium (see. The scheme 12, 13), uranium, thorium and other radioactive elements produced in nuclear reactors, including those which are nuclear waste cycles.
3. Any other components and industrial wastes containing a any actinides, mainly, thorium, uranium, plutonium, or as more commonly available and inexpensive in the market, any of these elements in any ratio among themselves.
4. Radioactive decay products plutonium series, uranium, thorium: radium, radon, polonium.
5. Polonium, being a product of microbiological decay actinides transmutation process elements for different rare isotopes of thallium, mercury, gold, platinum, including their stable isotopes.
6. Radioactive products (fragments) of plutonium and uranium fission - radioactive isotopes of strontium, yttrium, cesium, iodine, and other elements; their transmutation is suitable for the purpose of turning them into non-radioactive and non-hazardous to human elements and isotopes for environmental improvements.
7. All of the feedstocks (elements) used for the microbial treatment either separately or together in any ratio with each other.

A feed comprising any of the above radioactive elements treated with an aqueous solution of Thiobacillus spp, for example, the type of Thiobacillus aquaesullis or Thiobacillus ferro-oxidans, or a mixture thereof in any proportions relative to each other, or any kind of sulfur-oxidizing bacteria in the presence of elements with variable valency, in normal circumstances, the activity of microorganisms.

The method does not require expensive and hazardous to humans and environmental nuclear reactors conducted under conventional conditions in conventional containers at normal ambient temperature (it is quite acceptable values from 4 to 60 degrees Celsius), under normal atmospheric pressure, requires fresh water consumption.

Machinery

In our method, the microorganisms initiate and accelerate the alpha decay (-a), a beta-minus (-β), and beta-plus (+ β) decay (electron capture). Microorganisms captured in the nuclei of heavy elements (mainly in any f-elements and heavy s-elements) protons, alpha particle (two protons and two neutrons) and electrons (beta-minus decay), transferring thus trapped protons, alpha -particles and electrons to other elements, mainly for d- and p-elements, such as arsenic and iron.

Also, microorganisms may transfer protons, alpha particles, electrons and positrons to other elements, such as the f-ytterbium element, if present in the medium. Bacterial capture and detachment of protons, alpha particles and electrons occurs at the radioactive elements f-s-group and the group (according to the classification of the periodic system).

Also, the bacteria initiate and reproach beta plus (+ β) decay (electron capture) in the nuclei of beta-plus radioactive isotopes of elements of any group, transferring to the core elements of the electron data obtained in the process of beta-minus (-beta) decay of isotopes of other exposed beta-minus decay, or captured at present in the medium of variable valency elements (not radioactive) during their bacterial oxidation.

Bacterial proton transfer (P), alpha particles (α) and electron $^{(e}$ -) is carried out by elements of d-groups (for example, iron and other) to the elements p-groups (for example, arsenic and others) and s-group elements (strontium, cesium, radium and other).

Bacterial capture and detachment of protons, alpha particles and electrons occurs at alpha- and beta-radioactive isotopes f-group elements, s-p-groups and groups which are themselves naturally (natural) alpha- or beta-radioactive, wherein bacteria initiate and millions and billions of times accelerate the processes of alpha and beta decay.

Bio-alpha decay (-α)

During alpha decay, with loss of two protons nuclei elements f- s-groups and are converted into lighter elements (transition into two cells down the table of the periodic system).

After the capture and separation from the f- and s-components of protons and alpha particles, bacteria carry these protons and alpha particles in the various elements of the d-, p- and s-groups, turning them the other elements - on the following location in the periodic table of chemical elements (transfer to one or two cells on the front table of the periodic system).

In bacterial alpha-particle transfer of f-elements iron, nickel is converted into iron (see Table 1.); in bacterial transferring protons and alpha particles from the f-elements arsenic, arsenic is converted to bromine (see Table 1.); in bacterial transferring protons and alpha particles from the f-elements ytterbium, ytterbium converted into hafnium (see. Table 1).

Bio-beta decay (-β, + β)

Bacteria and provoke many times accelerate both types of beta decay: beta-minus decay and beta-plus decay.

Beta-minus decay (-β) - is a core electron emission, resulting in a proton neutron conversion element to convert the location to the next by a periodic system of chemical elements (shift one cell down the periodic table of elements of the system).

Beta decay plus (+ β) - electron capture nucleus, resulting in the conversion of a proton to a neutron conversion element according to the previous location in the periodic system of chemical elements (transition to single cell backward in the periodic table of the system).

In the process triggered by bacteria and accelerated beta decay, in some cases, there is a consequent emission of so-called delayed neutron - is spontaneous, natural way according to the laws of physics of isotope decay and transitions to give a lighter isotope of a given element. Using the emission mechanism of the delayed neutron allows to further expand the list of received elements and isotopes, and also to predict and regulate the bio-transmutation process (to stop it at the right time).

The bacteria initiate and accelerate beta decay - the emission of an electron and the nucleus of the introduction of the electron to the nucleus (electron capture) of beta-radioactive chemical elements.

The bacteria initiate and accelerate the beta decay isotopes of elements as raw materials initially contained in a medium, and isotopes of elements obtained artificially bioprocess bacteria instigated after alpha decay. This fact - beta decay occurring after bacterial-induced alpha decay has great practical significance for the purpose of obtaining scarce energy-important elements and isotopes.

Bacteria gripped and torn away electrons also have more light, as compared with f-elements, nuclei, and just at the beta-minus radioactive isotopes - products ("fragments") dividing the uranium and plutonium, for example, strontium-90 nuclei, yttrium-90 , iodine-129, iodine-130, cesium-133, cesium-137 and certain other elements which are converted in the process of beta decay into stable elements. In this chemical element in the core a neutron conversion occurs in a proton, and a sequence number offset by one element or two (depending on the initial isotope) cell forward periodic table of elements.

This process allows you to radically and environmentally friendly to dispose of highly radioactive waste of nuclear plants and nuclear power plants, ie Nuclear-fuel combustion products that contain radioactive elements - "fragments" of the fission of uranium, plutonium and other transuranic elements - actinides and fission products of thorium, in the case of its use in the thorium nuclear cycle.

An electron captured by bacteria in the beta-minus decay, the bacterium was transferred to a kernel plus beta-radioactive isotopes of elements (in the case of their presence in the environment). In the process go as redox reactions.For example, the latter is converted into iron (II), the latter is converted into arsenic (III) in bacterial electron transfer to arsenic (V) in bacterial electron transfer to the iron (III).

Bacterial cell surface charge caused by dissociation of ionic groups of the cell wall, which consists of proteins, phospholipids and lipopolysaccharides. At physiological pH microbial cells, bacteria bear on their surface an excess negative charge which is formed by the dissociation of ionic, preferably acidic groups of the cell surface.

The negatively charged surface of the microbial cells from the environment attracts oppositely charged ions, which are under the influence of electrostatic forces tend to approach the ionized groups of the cell membrane. As a result, the cell is surrounded by an electric double layer (adsorption and diffusion).

Charge cell continuously varies depending on the processes occurring in the environment. When exposed to alpha particles, negatively charged cells decreases (in absolute value) and converted into a positive charge, which speeds up the process of beta decay.

Next, under the influence of the electrons liberated by beta decay of radioactive elements, as well as the electrons that have fallen out of the elements of variable valence in reduced form in the adsorption layer of microorganisms, the negative charge of microorganisms increases (in absolute value), turns from positive to negative, which accelerates processes of alpha-decay-pulling positively charged protons and alpha particles from the atoms of chemical elements.

These processes are accelerating due to electrical interactions negatively and positively charged groups of the surface of the cells with alpha and beta particles, radioactive elements, respectively. The logarithmic growth stage of microorganisms negative charge of the cell reaches its maximum value, which leads to a maximum rate of transformation, the transformation elements. Processes of conversion of chemical elements can occur both within the bacterial cells and on the cell wall surface of the adsorption layer in the electric double layer.

Thus, the microbial cells, labile changing their charging performance, are accelerating and regulating the system of several kinds of radioactive decay and transformation of one element into another. To accelerate the process of transmutation of the chemical elements microorganisms when charge microorganisms approaching the isoelectric point in the reaction solution used surfactants (surfactant). Polyampholytes, ionic surfactants, both anionic and cationic surfactant introduced into the reaction medium, by changing the charge cell (charge shift of isoelectric point in the negative or positive direction), promote bacterial initiation and intensification of chemical transmutation (Example 9).

Industrial, scientific and technical importance of the invention

Microbiological method for the transmutation of elements, the acceleration of nuclear reactions and isotopic transitions, allows unlimited quantities of produce valuable and scarce radioactive elements, which are in high demand in the market, technology, industry and research. These elements and isotopes are enormous reserves of energy, have an extremely high value and selling price on the market.

The following highlights the small and rare in the nature of the content of chemical elements and their isotopes data, the complexity of their production in nuclear reactors, resulting in their global production is negligible, and the market price is very high. Also described are the application received by the elements and the global demand for them.

Polonium

Polonium is always present in uranium and thorium minerals, but in such minute quantities that getting it from ores known traditional methods impractical and uneconomic. The equilibrium content of polonium in the crust - about 2×10^{-14} % by weight. Microquantities polonium extracted from the waste processing of uranium ores. Allocate polonium extraction, ion exchange chromatography and sublimation.

The main industrial method of obtaining polonium is its artificial synthesis by nuclear reactions, which is expensive and unsafe.

Polonium-210 in alloys with beryllium and boron is used for the production of compact and very powerful neutron sources, virtually creating a gamma-radiation (but short-lived because of the short lifetime $^{of\ 210}$ the Po: the $T_{1/2}$ = 138.376 days) - alpha particles of polonium-210 give rise to neutrons in the nuclei of beryllium or boron (α, n) -reaction.

This sealed metal ampoules, in which lies covered with polonium-210 ceramic pellets of boron carbide carbide or beryllium. Such neutron sources are light and portable, it is safe to use and very reliable. For example, the Soviet neutron source VNI-2 is a two brass vial diameter and a height of four centimeters, every second radiating up to 90 million neutrons.

Polonium is sometimes used to ionize the gas, in particular air. The first ionization of air is needed to deal with static electricity (at work, when dealing with particularly sensitive equipment). For example, for precision optics made dusting brush.

An important application of polonium is its use in the form of alloys with lead, yttrium or alone for the production of powerful and highly compact source of heat for the stand-alone installations, such as space or polar. One cubic centimeter of polonium-210 releases about 1320 watts of heat. For example, the Soviet space program of self-propelled vehicles "Lunokhod" to heat the instrument compartment heater used polonium.

Polonium-210 can serve as a light alloy with lithium isotope (^{6}Li) substance that can substantially reduce the critical mass of nuclear charge and serve as a kind of nuclear detonator.

So far, industrial and commercial (market) amounts of polonium were milligrams and grams of polonium.

Radium

At the time of the radium used in compact neutron sources, for this small amount is fused with beryllium. Under the action of alpha radiation from beryllium neutrons are knocked out $^{9}Be + ^{4}He \rightarrow ^{12}C + ^{1}n$.

The medicine is used as a source of radium radon, including radon baths for cooking. Radium is used for short-term irradiation in the treatment of malignant diseases of the skin, nasal mucosa, urinary tract.

Low use of radium is due, in particular, with its negligible content in the crust and in the ores, and the high cost and complexity of obtaining artificially in nuclear reactions.

During the time that has elapsed since the discovery of radium - more than a century - around the world managed to get only 1.5 kg of pure radium. One ton of pitchblende, from which the Curies received radium, contained only about 0.0001 gram of radium-226. All natural radium is radiogenic - it arises from the decay of uranium-238, uranium-235 and thorium-232.

In equilibrium, the ratio of the uranium-238 and radium-226 in the ore is equal to the ratio of half-periods: $(4.468 \times 10^{9}$ years$) / (1617) = 2,789 \times 10^{6.}$ Thus, for every three million uranium atoms in nature it represents only one atom of radium. Microbiological method for the transmutation of chemical elements can be obtained from uranium and thorium, radium-226 and other isotopes of radium in virtually unlimited quantities (kilograms, tons) and to extend the scope of radium and its isotopes.

Frances

Currently, France and its practical application have salt, due to short half-life. From well-known by far the most long-lived isotope ^{223}Fr France has a half-life of 22 minutes. However, obtaining microbiologically France transmutation of the chemical elements and fixation devices for the presence of France in treated samples (Figures 4, 5, 6, 7, 9, 14), in the absence of France in the feedstock, the general course of processes proves conversion elements. In the future, it is possible to use in France and other scientific purposes.

Actinium

Actinium is one of the less common naturally radioactive elements. Its total content in the crust of less than 2600 m, while, for example, the amount of radium over 40 Mill. T. In nature, found 3 actinium isotope ^{225}Ac, ^{227}Ac, ^{228}Ac.Actinium accompanies uranium ores.

Getting actinium from uranium ore known traditional methods is impractical because of the paucity of its content in them, and the great similarity with the present there is rare earth elements.

Significant amounts of the isotope ^{227} Ac get radium irradiation by neutrons in a reactor. ^{226} Ra (n, γ) → ^{227} Ra (-β) →^{227} Ac. The yield is usually not more than 2.15% of the initial amount of radium. Number actinium in this method of synthesis is calculated in grams. The isotope ^{228} Ac obtained by irradiation of the isotope ^{227} Ac neutrons.
^{227} Ac beryllium mixed with a source of neutrons.
Ac-Be-sources are characterized by low yield of gamma-ray activation analysis used in the determination of Mn, Si, Al in the ores.
^{225} Ac applied to obtain ^{213} Bi, as well as for use in radioimmunotherapy.
^{227} Ac can be used in radioisotope energy sources.
^{228} Ac is used as a tracer in chemical research due to its high-.beta.-radiation.

A mixture of isotopes Ac- ^{228} ^{228} Ra is used in medicine as an intense source of gamma-rays.

Actinium can be a powerful source of energy that has not yet been applied because of the high cost of actinium and small amounts of actinium obtained by known methods, and because of the complexity of its receipt by known methods. All the traditional techniques for making and isolating actinium are expensive, uneconomical and dangerous to human health and the environment. Getting actinium microbiological method of transmutation of chemical elements produces Actinium isotopes and cheap at cost and safe way in unlimited quantities (kilograms, tons, tons, etc.).

Protactinium

Due to the small content in the earth's crust (the content of the Earth's mass is 0.1 billionth of a percent) of the element to date it has a very narrow application - the addition to nuclear fuel.

From natural sources - residues from the processing of pitchblende - conventional methods can only protactinium-231 (^{231} Pa). In addition, ^{231} Pa conventional method can be obtained by irradiation of thorium-230 (^{230} Th) slow neutrons:

$$^{230}\mathrm{Th}(n, \gamma) \rightarrow {}^{231}\mathrm{Th}\ (\beta^{-}\text{-распад},\ T_{1/2} = 25.6\ \text{ч}) \rightarrow {}^{231}\mathrm{Pa}$$

Isotope ^{233} Pa is also derived from thorium:

$$^{232}\mathrm{Th}(n, \gamma) \rightarrow {}^{233}\mathrm{Th}\ (\beta^{-}\text{-распад},\ T_{1/2} = 22.12\ \text{мин.}) \rightarrow {}^{233}\mathrm{Pa}$$

As an additive to the nuclear fuel material is added at the rate of protactinium protactinium 0.34 grams per 1 ton of uranium, which is very significantly increases the energy value of uranium and uranium combustion efficiency (a mixture of uranium and protactinium).

Get the protactinium microbiological method of transmutation of chemical elements produces protactinium cheap at cost and safe way in unlimited quantities (kilograms, tons, tons, etc.). Get the protactinium microbiological method of transmutation of chemical elements decide on the availability of cheap energy, raw materials and energy products with high efficiency, and meets the needs of protactinium in other areas of science and technology.

Thorium

Different isotopes of thorium (thorium-227, thorium-228, thorium-230, thorium-234 and others), having different half-lives that are not contained in natural thorium obtained microbiological method of transmutation of chemical elements, are of interest for research purposes, and It is of interest as well as sources of energy and raw material for other elements and isotopes.

Uranium isotopes

Currently, 23 known artificial radioactive uranium isotopes with mass numbers from 217 to 242. The most important and valuable isotopes of uranium - uranium-233 and uranium-235. U-233 (^{233} $_{U,}$ T 1/2 = 1,59 · ^{10} May s) obtained by irradiation with neutrons thorium-232 and is able to divide exposed to thermal neutrons, making it a promising fuel for nuclear reactors:

$^{232}Th(n, \gamma) \rightarrow {}^{233}Th$ (β^--распад, $T_{1/2}$ = 22,12 мин.) $\rightarrow {}^{233}Pa$(β^--распад, $T_{1/2}$ = 27 суток) $\rightarrow {}^{233}U$ but this process is very complicated, expensive and environmentally hazardous. The content of valuable isotope uranium-235 $(^{235}$ U) in natural uranium is small (0.72% of natural uranium), and its traditional separation from other uranium isotopes (eg, laser centrifugation) and the selection is associated with great technical, economic and environmental challenges, as it is costly, expensive and complex equipment, and safe for humans and the environment. The isotope uranium 233 $(^{233}$U) in natural uranium is not contained, and its traditional reception in nuclear reactors is associated with the same difficulties and dangers.

Uranium is widely distributed in nature. The uranium content in the crust is 0.0003% (wt.) concentration in the sea water 3 g / l. The amount of uranium in the layer thickness of the lithosphere 20 km is estimated to be 1.3×10^{14}tons.

The world uranium production in 2009 was 50,772 tons, the world's resources for 2009 amounted to 2,438,100 tons. Thus, the world's uranium reserves and the world production of natural uranium are large enough.

The problem is that most of the reserves and production (99.27%) are in the natural isotope uranium-238, uranium (respectively, the percentage of isotopes in natural uranium), ie the least useful and least energetic isotope of uranium.

Besides the traditional separation of uranium isotopes from each other (in this case, the uranium-235 from uranium-238) is extremely difficult, expensive and environmentally unsafe. According to OECD data, the world's 440 operating nuclear reactors for commercial use, which consumes annually 67 ths. Tons of uranium.

This means that its production provides only 60% of its consumption (the rest is extracted from old nuclear warheads). The most valuable in this case, the isotopes of uranium - uranium-233 and uranium-235 (the nuclear fuel) for which and reused after reprocessing of spent fuel rods from nuclear power plants and de-alerting of nuclear warheads.

The nuclei $^{\text{of } 238}$ U divided only when capturing fast neutrons with an energy of at least 1 MeV. The nuclei $^{\text{of } 235}$ U and ^{233} U divided in the capture of as slow (thermal) and fast neutrons, and are divided spontaneously, which is particularly important and valuable.

Microbiological method for the transmutation of chemical elements allows virtually unlimited quantities produced from natural uranium (from the isotope uranium-238), a rare and valuable isotopes of uranium - uranium-232, uranium-233, uranium-234, uranium-235, uranium-236, as well as other valuable chemical elements and their isotopes: neptunium-236, neptunium-237, neptunium-238, plutonium-236, plutonium-238, americium-241, protactinium-231, protactinium-234, thorium-227, thorium-228, thorium-230 actinium-227, radium-226, radium-228, radon-222, polonium-209, polonium-210. Industrial, technical and energy value as well as the selling market value of these elements obtained much higher than the original element - uranium-238.

Neptunium

Neptunium is encountered on Earth only in trace amounts, it has been artificially produced from uranium by nuclear reactions.

Contents $^{\text{of } 237}$ Np in the irradiated uranium fuel is low, and is estimated to be approximately equal to 0.1-0.3% of the resultant plutonium or $10^{-4} \cdot 10^{-6\%}$ by weight of the uranium content. When using uranium fuel enriched in $^{\text{the}}$isotopes ^{235} U and ^{236} U, Np-237 is produced mainly by the following nuclear reaction:

$$^{235}_{92}U(n, \gamma)^{236}_{92}U(n, \gamma)^{237}_{92}U \xrightarrow[6,75\ d]{\beta^-\ 518,6\ keV} {}^{237}_{93}Np$$

.

By neutron irradiation of neptunium-237 is obtained by weight amounts of isotopically pure plutonium-238, which is used in small radioisotope power sources, RTGs (RTG - Radio-isotope thermoelectric generator), in pacemakers, as a heat source in radioisotope power sources and neutron sources .

The critical mass of neptunium-237 is about 57 kg of a pure metal, and thus the isotope can be practically used to produce nuclear weapons.

Americium

Americium-241 is produced by neutron irradiation of plutonium:

$$^{239}Pu(n,\gamma) \rightarrow {}^{240}Pu(n,\gamma) \rightarrow {}^{241}Pu(\beta^-, T_{1/2} = 13 \text{ лет}) \rightarrow {}^{241}Am$$

Americium-241 - valuable rare chemical elements and isotopes, its traditional reception in nuclear reactors is associated with the usual for actinide complex and expensive as a result of americium has a larger market value, demand and can be used in various fields of science, industry and technology.

Microbiological method for the transmutation of chemical elements allows to get practically unlimited quantities of neptunium-236, neptunium-237, neptunium-238, plutonium-236, plutonium-238, americium-241 and other isotopes of neptunium, plutonium and americium.

Conventional short designations in the following diagrams and tables:
Uranium-238, the U^{238} - here - 238 - is the relative atomic mass, ie, the total number of protons and neutrons.
P - proton.
Or N n - a neutron.
alpha - alpha particle, ie, two protons and two neutrons.

(-ɑ) - Alpha particle emitted from the atom (from the element) in our reactions, with the sequence number (nuclear charge) is decreased by two units, and the element is converted into lighter disposed through a cell in Mendeleev's periodic table of elements (in two shift cells back). Relative atomic mass is then decreased by four units.

Beta decay - making, in which the element (nuclear charge) serial number of changes to the unit and the relative atomic mass (the total number of protons and neutrons) remains constant.

(+ B) - emission of a positively charged positron particles, or the seizure of a negatively charged electron is the core: in both cases, the serial number (nuclear charge) of the element is reduced by one.

Observed phenomenon of emission of so-called "delayed neutrons" (usually one or two) after beta decay. At the same time, the new formed by the beta decay of a chemical element, after the emission of delayed neutrons (neutrons) retains its new location, and the cell in the periodic table of the system elements, as it saves the nuclear charge (number of protons), but lost in the atomic weight, forming new , lighter isotopes
.
(-n) - «Delayed neutron" neutron emitted from an atom after beta decay, and the atomic weight of the new element is reduced by one
.
(-2n) - Two "delayed neutrons", emitted from an atom after beta decay, the atomic mass of the new element is reduced by two units.

(Ӑ) - «retarded» alpha particle (kind of isotope decay) emitted from the atom (element) after beta decay. At the same sequence number (nuclear charge) decreases by two units, and the relative atomic mass of the element is reduced by 4 units.

There is another transmutation of the chemical element (shift of two cells on the back table of chemical elements of the periodic system). $_T$ 1/2, or T - the half-life of the isotope element.

The authors conducted a series of successful reproducible experiments with a variety of ores and raw materials.

Feedstock containing radioactive elements, treated with aqueous genus Thiobacillus bacteria in the presence of variable valence elements all s, p, d and f elements, creating a standard redox potential (for ^{example,} Sr 2+, nitrogen ^{N}5+ / N 3-, sulfur ^{S} 6+ / S 2- arsenic ^{As} 5+ / As 3+, iron ^{Fe} 3+ / Fe 2+, Mn ^{Mn} 4+ / Mn 2+, molybdenum ^{Mo} 6+ / Mo 2+, Co ^{Co}3+ / Co $^{2+,}$ vanadium ^{V} 5+ / V 4+, etc).

Various bacteria of the genus Thiobacillus have been used, and iron-sulfur-oxidizing bacteria (thermophilic and others) involved in redox processes of metals, always achieved positive effect.

The authors conducted experiments in 2536. The experimental data is statistically processed (see. Table 1, 2, 3, 4) and are reflected in the schemes produce microbiological method of uranium-238 (238U) and thorium-232 variety of isotopes of uranium, protactinium, thorium, actinium, radium, polonium and other elements (see FIG. 1 to 17, schemes 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13).

Schemes reactions and isotopic transitions do not contradict and confirm the existing theory of radioactive decay.

Example 1.

For transmutation of the chemical elements and receiving elements and isotopes new feedstock microbial treatment using Saudi sulfide ores containing uranium and thorium (Table 1, Figures 1, 2, 3, 4, 5, 6, 7). Saudi ore also contained the elements phosphorus, arsenic, vanadium, mostly in oxidized form (phosphates, arsenates, vanadates), and iron - both in an oxidized and in a reduced form.

Therefore, to create a high redox potential in the fermentation raw material treated with microorganisms Thiobacillus acidophilus strain DSM-700 in aqueous solution with a variable valence elements present in the solution in a reduced form: Mn $^{+4,}$ Co $^{+2,}$ Fe $^{+2,\ -3}$ N, ^{S} -2 (in salt form), in their total weight 0.01% by weight of the medium.

When growing microorganisms Thiobacillus acidophilus strain 700 DSM-used standard culture media (e.g., Waksman and Leathen environment for Thiobacillus ferrooxidans, and 9K medium medium other iron and sulfur-oxidizing bacteria).

The standard nutrient medium were added variable valency elements - transelementy (electrons carrying elements, e.g., Mg, Mn, Co, Mo, Zn, Cu, Fe in the form of salts) in their total weight 0.01% by weight of the medium, organic materials hydrolysis products

For example, hydrolysis of fish waste, meat, or the timber (2% by weight of the medium) and raw material (uranium or thorium or ore containing radioactive waste in an amount of 1.5% by weight of the medium). The fermentation medium comprising 10% of raw materials (ores) was added 10% solution of the culture medium with optional autotrophic microorganisms selected in the exponential growth phase.

Transmutation process was carried out in ten fermentation shake flasks. PH of the solution was adjusted to 10 normal sulfuric acid, pH of the solution was maintained in the range 0.8-1.0 in. The temperature of the process of 28-32 degrees Celsius.

The redox potential (Eh) of the solution in the logarithmic transmutation process step is 635 mV.stirring rate 300 rpm. The ratio of solids to liquid was 1:10 (100 grams ore per liter aqueous solution). Every day, every 24 hours was measured by pH and Eh of the solution, the concentration of chemical elements and isotopes in the solution, and track the activity of microorganisms.

The process was conducted for nine days. Use the method of analysis of aqueous solutions and ore: for the determination of elements using X-ray fluorescence method, the type of devices: of CYP-02 "Wren PV"; S2 PICOFOX. Also we are using atomic-absorption method. The isotopic composition was determined by mass spectroscopy.

Charging characteristics of microbial cells was determined by electrophoretic mobility in an automatic microscope Parmoquant-2. According to the devices determined by the qualitative and quantitative composition of the end products.

The results of these experiments and statistically processed according to the process of time are shown in Table 1. FIG. 1 shows a spectrogram of the original ore Saudi Arabia without microbiological treatment and without transformation of chemical elements. Figures 2, 3, 4, 5, 6, 7 show spectrogram analysis transmutation of the chemical elements in the microbiological treatment of ore Saudi depending of process time after 48 hours (day 2), 72 hours (3 days), 120 hours (5 days), 120 hours (5 days) after 168 hours (7 days) after 192 hours (8 days), respectively.

Элементы	Период полураспада $T_{1/2}$	Содержание элементов в 100 г руды, мг	Количество мг элементов в 1 литре раствора на 100 г руд мг элемента/100 г руды в 1 л раствора. (Руда Саудовской Аравии, массовая доля						
			Сутки						
			1	2	3	4	5	6	7
^{238}U	$4{,}5 \times 10^{9}$ Лет	62,0	62,0	43,6	17,2	4,2	0	0	0
^{234}Th	24,1 суток	0	0	11,01	12,61	8,57	6,23	4,01	2,98
^{234}Pa	6,66 час	0	0	3,08	1,87	1,69	1,38	1,02	0,71
^{233}Pa	27 сут.	0	0	0	3,23	3,62	3,72	3,54	2,97
^{232}Pa	1,31 суток	0	0	0	5,46	6,63	2,14	0,53	0,28
^{231}Pa	$3{,}43 \times 10^{4}$ лет	0	0	0	0	5,73	6,85	6,90	7,09
^{236}U	2×10^{16} лет	0	0	0	9,14	8,45	8,26	6,96	6,77
^{235}U	$1{,}62 \times 10^{5}$ лет	0	0	0	7,64	7,93	7,73	7,51	6,29
^{232}U	8×10^{13} л, 74 г	0	0	0	0	6,14	7,31	6,65	4,03
^{232}Th	$1{,}39 \times 10^{10}$ лет	4,00	4,00	0	0	0	0	0	0
^{228}Ra	6,7 года	0	0	2,80	2,56	0	0	0	0
^{227}Ac	21,6 год	0	0	5,15	5,37	8,91	12,02	15,11	15,20
^{230}Th	8×10^{4} лет	0	0	0	0	1,74	2,53	2,01	1,78
^{225}Ra	1617 г	0	0	0	0	0	1,71	1,93	1,09
^{210}Po	138,4 суток	0	0	0	0	0,20	1,01	2,25	6,25
^{209}Po	103 г	0	0	0	0	0	0,61	1,32	2,74
^{208}Po	2,93 г	0	0	0	0	0	0,20	1,08	2,73
^{56}Fe	Стабил.	201,87	201,87	201,71	201,48	201,23	201,01	200,59	200,47
^{60}Ni	Стабил.	0	0	0,1	0,21	0,34	0,46	0,68	0,75
^{55}Mn	Стабил.	143	143	143,08	143,19	143,31	143,42	143,63	143,69
^{75}As	Стабил.	270	270	269,80	269,48	269,16	268,86	268,30	268,12
^{79}Br	Стабил.	0	0	0,11	0,28	0,45	0,61	0,91	1,00
^{71}Ga	Стабил.	0	0	0,09	0,25	0,40	0,54	0,80	0,89
^{175}Yb	Стабил.	0,02	0,02	0,01	0,005	0	0	0	0
^{177}Hf	Стабил.	0	0	0,01	0,015	0,021	0,021	0,021	0,021
Pt		0	0	0	0	0,26	0,39	0,85	0
Hg		0	0	0	0	0	1,01	1,65	1,94
Au		0	0	0	0	0	0	0	0,18

Таблица 1. Результаты трансмутации химических элементов и превращения изотопов в процессе микробиологичес
руды Саудовской Аравии, содержащей уран-238 и торий-232.

Figure 1. Preparation of microbially produced from uranium 238 (^{238}U) of different isotopes of uranium, protactinium, thorium, actinium, radium, polonium:

$^{238}U(-\alpha)\rightarrow{}^{234}Th(-\beta)\rightarrow{}^{234}Pa(-n)\rightarrow{}^{233}Pa(-\beta)\rightarrow{}^{233}U(-2n)\rightarrow{}^{231}U(+\beta)\rightarrow{}^{231}Pa(-\alpha)\rightarrow{}^{227}Ac(-\beta)\rightarrow$

$\rightarrow{}^{227}Th(-n)\rightarrow{}^{226}Th(-\alpha)\rightarrow{}^{222}Ra(-\alpha)\rightarrow{}^{218}Rn(-\alpha)\rightarrow{}^{214}Po(-\alpha)\rightarrow{}^{210}Pb(-\beta)\rightarrow{}^{210}Bi(-\beta)\rightarrow{}^{210}Po$

$^{210}Po(-n)\rightarrow{}^{209}Po$

$^{210}Po(-2n)\rightarrow{}^{208}Po$

Figure 2. Preparation of protactinium-231 $^{(231}$ Pa) microbially produced from uranium 238 $^{(238}$ U) in various ways.

2-1. $^{238}U(-\alpha)\rightarrow{}^{234}Th(-\beta)\rightarrow{}^{234}Pa(-n)\rightarrow{}^{233}Pa(-\beta)\rightarrow{}^{233}U(-2n)\rightarrow{}^{231}U(+\beta)\rightarrow{}^{231}Pa$

2-2. $^{238}U(-\alpha)\rightarrow{}^{234}Th(-\beta)\rightarrow{}^{234}Pa(-2n)\rightarrow{}^{232}Pa(-\beta)\rightarrow{}^{232}U(-n)\rightarrow{}^{231}U(+\beta)\rightarrow{}^{231}Pa$

Scheme 4. Preparation of thorium-230 $^{(230}$ Th) microbially produced from uranium 238 $^{(238}$ U).

4-1. $^{238}U(-\alpha)\rightarrow{}^{234}Th(-\beta)\rightarrow{}^{234}Pa(-\beta)\rightarrow{}^{234}U(-\alpha)\rightarrow{}^{230}Th$

Next, the process stops or $^{(230}$ and excreted Th), if the thorium-230 is the ultimate goal of the process. Or, the process continues to produce valuable and rare radioactive isotopes of radium $^{(226}$ Ra), radon, astatine, polonium, bismuth, lead:

4-2. $^{230}Th(-\alpha)\rightarrow{}^{226}Ra(-\alpha)\rightarrow{}^{222}Rn(-\alpha)\rightarrow{}^{218}Po(-\beta)\rightarrow{}^{218}At(-\beta)\rightarrow{}^{218}Rn(-\alpha)\rightarrow{}^{214}Po(-\alpha)\rightarrow{}^{210}Pb(-\beta)\rightarrow$

$\rightarrow{}^{210}Bi(-\beta)\rightarrow{}^{210}Po$

$^{210}Po(-n)\rightarrow{}^{209}Po$

$^{210}Po(-2n)\rightarrow{}^{208}Po$

Scheme 5. Preparation of Actinium-227 $^{(227}$ Ac) microbially produced from uranium 238 $^{(238}$ U) in various ways.

5-1. $^{238}U(-\alpha)\rightarrow{}^{234}Th(-\beta)\rightarrow{}^{234}Pa(-n)\rightarrow{}^{233}Pa(-\beta)\rightarrow{}^{233}U(-2n)\rightarrow{}^{231}U(+\beta)\rightarrow{}^{231}Pa(-\alpha)\rightarrow{}^{227}Ac$

5-2. $^{238}U(-\alpha)\rightarrow{}^{234}Th(-\beta)\rightarrow{}^{234}Pa(-2n)\rightarrow{}^{232}Pa(-\beta)\rightarrow{}^{232}U(-n)\rightarrow{}^{231}U(+\beta)\rightarrow{}^{231}Pa(-\alpha)\rightarrow{}^{227}Ac$

Figure 6. Production of radium-226 $^{(226}$ Ra) and radium-228 $^{(228}$ Ra) microbiological method of uranium-238 (the $U^{238)}$ (see. 6-1) and from natural thorium-232 $^{(232}$ of Th) (see. 6 -2), respectively:

6-1. $^{238}U(-\alpha)\rightarrow{}^{234}Th(-\beta)\rightarrow{}^{234}Pa(-\beta)\rightarrow{}^{234}U(-\alpha)\rightarrow{}^{230}Th(-\alpha)\rightarrow{}^{226}Ra$

6-2. $^{232}Th(-\alpha)\rightarrow{}^{228}Ra$

Scheme 7. Preparation of the most valuable and stable isotopes of polonium $^{(210}$ Po, ^{209} Po, ^{208} Po) microbially produced from uranium 238 $^{(238}$ U).

7-1. $^{238}U(-\alpha)\rightarrow{}^{234}Th(-\beta)\rightarrow{}^{234}Pa(-n)\rightarrow{}^{233}Pa(-\beta)\rightarrow{}^{233}U(-2n)\rightarrow{}^{231}U(+\beta)\rightarrow{}^{231}Pa(-\alpha)\rightarrow$

$\rightarrow{}^{227}Ac(-\beta)\rightarrow{}^{227}Th(-n)\rightarrow{}^{226}Th(-\alpha)\rightarrow{}^{222}Ra(-\alpha)\rightarrow{}^{218}Rn(-\alpha)\rightarrow{}^{214}Po(-\alpha)\rightarrow{}^{210}Pb(-\beta)\rightarrow$

$\rightarrow{}^{210}Bi(-\beta)\rightarrow{}^{210}Po$

$^{210}Po(-n)\rightarrow{}^{209}Po$

$^{210}Po(-2n)\rightarrow{}^{208}Po$

7-2. $^{238}U(-\alpha)\rightarrow{}^{234}Th(-\beta)\rightarrow{}^{234}Pa(-2n)\rightarrow{}^{232}Pa(-\beta)\rightarrow{}^{232}U(-n)\rightarrow{}^{231}U(+\beta)\rightarrow{}^{231}Pa(-\alpha)\rightarrow{}^{227}Ac\rightarrow$

далее путь превращений элементов и изотопов до ^{210}Po,^{209}Po,^{208}Po идентичен схеме 7-1.

7-3. $^{238}U(-\alpha)\rightarrow{}^{234}Th(-\beta)\rightarrow{}^{234}Pa(-\beta)\rightarrow{}^{234}U(-n)\rightarrow{}^{233}U(-\alpha)\rightarrow{}^{229}Th(-\alpha)\rightarrow{}^{225}Ra(-\beta)\rightarrow$

$\rightarrow{}^{225}Ac(-n)\rightarrow{}^{224}Ac(+\beta)\rightarrow{}^{224}Ra(-\alpha)\rightarrow{}^{220}Rn(-\alpha)\rightarrow{}^{216}Po(-\alpha)\rightarrow{}^{212}Pb(-\beta)\rightarrow{}^{212}Bi(-n)\rightarrow{}^{211}Bi(-\beta)\rightarrow$

$\rightarrow{}^{211}Po(-n)\rightarrow{}^{210}Po$

$^{211}Po(-2n)\rightarrow{}^{209}Po$

Figure 8. Production of various isotopes of thorium, actinium, radium, polonium microbially produced from natural thorium-232 (^{232} Th):

$^{232}Th(-\alpha)\rightarrow{}^{228}Ra(-\beta)\rightarrow{}^{228}Ac(-n)\rightarrow{}^{227}Ac(-\beta)\rightarrow{}^{227}Th(-n)\rightarrow{}^{226}Th(-\alpha)\rightarrow{}^{222}Ra(-\alpha)\rightarrow{}^{218}Rn(-\alpha)\rightarrow$

$\rightarrow{}^{214}Po\ (-\alpha)\rightarrow{}^{210}Pb\ (-\beta)\rightarrow{}^{210}Bi\ (-\beta)\rightarrow{}^{210}Po$

$^{210}Po(-n)\rightarrow{}^{209}Po$

$^{210}Po(-2n)\rightarrow{}^{208}Po$

Example 2.

The method of the process is the same as in Example 1. The chemical transmutation and producing new elements and isotopes in the feedstock used for the microbial treatment uranium ore North-West Africa containing uranium, thorium, arsenic and sulfur in reduced form (metal sulfides arsenide, sulphoarsenides).

Therefore, to create a high redox potential feedstock treated microorganisms Thiobacillus aquaesulis strain DSM-4255 in an aqueous solution with a variable valence elements, in solution in the oxidized $^{\text{form:}}$ N +5, $^{+5}$ P (in the form of $^{\text{phosphates),}}$ As +5, S $^{+6,}$ Fe $^{+3,}$Mn $^{+7,}$ their total weight 0.01% by weight of the medium.

The redox potential (Eh) of the solution in the logarithmic transmutation process step is 798 mV. The temperature of the process of 30-35 degrees Celsius, pH 2-2.5 environment. The time of the twenty-day process.

The results of these experiments and statistically processed according to the time of the process are given in Table 2.

The spectrograms analysis of chemical elements in transmutation microbial processing of uranium ore North-West Africa as a function of time of the process, after 24 hours (1 day) after 144 hours (6 days), after 168 hours (7 days) after 192 hours (8 days), after 480 hours (20 days) are shown in figures 8, 9, 10, 11, respectively.

Элементы	Период полураспада $T_{1/2}$	Содержание элементов в 100 г руды, мг	Количество мг элементов в 1 литре раствора мг элемента/100 г руды в 1 л раств (Руда Северо-Западной Африки, массовая доля ур					
			Сутки					
			1	2	3	4	5	6
^{238}U	4,5x10⁹ Лет	280,0	280,0	250,7	190,12	140,05	102,3	65,88
^{234}Th	24,1 суток	0	0	23,20	22,09	20,99	19,77	18,01
^{234}Pa	6,66 час	0	0	5,60	10,62	10,05	7,87	6,99
^{233}Pa	27 сут.	0	0	0	9,39	8,53	7,46	6,96
^{232}Pa	1,31 суток	0	0	0	12,28	8,00	7,05	6,73
^{231}Pa	3,43 x 10⁴ лет	0	0	0	0	20,40	40,02	53,03
^{227}Ac	21,6 год	0	0	0	0	0	31,32	69,99
^{234}U	2 x10¹⁶ лет	0	0	0	27,92	19,49	12,06	8,11
^{233}U	1,62 x 10⁵ лет	0	0	0	5,89	16,27	20,47	16,19
^{232}U	8 x10¹³ лет, 74 г	0	0	0	0	25,72	20,65	16,55
^{230}Th	8 x 10⁴ лет	0	0	0	0	4,62	4,43	3,49
^{226}Ra	1617 г	0	0	0	0	2,67	2,14	1,71
^{210}Po	138,4 суток	0	0	0	0	0	0	0
^{209}Po	103 г	0	0	0	0	0	0	0
^{208}Po	2,93 г	0	0	0	0	0	0	0

Таблица 2. Результаты трансмутации химических элементов и превращения изотопов в процессе микроб урановой руды Северно-Западной Африки.

Элементы	Продолжение таблицы 2 Количество мг элементов в 1 литре раствора на 100 г ру мг элемента/100 г руды 1 л раствора. (Руда Северо-Западной Африки, массовая доля урана ^{238}U =							
	Сутки							
	10	11	12	13	14	15	16	17
^{238}U	14,65	8,39	4,08	2,61	0	0	0	0
^{234}Th	6,22	4,05	1,99	1,09	0,49	0	0	0
^{234}Pa	4,54	3,96	3.44	2,85	2,36	1,47	0	0
^{233}Pa	4,81	3,96	3,40	3,04	2,61	1,77	0,99	0,5
^{232}Pa	4,61	3,72	3,07	2,76	1,97	1,00	0,68	0
^{231}Pa	80,27	50,11	29,12	17,48	11,96	9,23	0,58	0,38
^{227}Ac	110,77	151,77	180,18	193,61	201,27	206,78	215,81	215,44
^{234}U	6,00	5,68	4,73	3,86	3,07	2,29	1,58	0,81
^{233}U	4,70	1,67	1,35	0,95	0,60	0,26	0,12	0,08
^{232}U	8,06	6,97	4,24	3,85	3,46	2,66	1,68	0,83
^{230}Th	2,13	1,62	1,07	0,60	0,18	0,14	0,08	0,05
^{226}Ra	0,33	0,29	0,25	0,19	0,15	0,13	0,11	0,047
^{210}Po	8,63	10,53	12,75	14,86	16,81	18,55	19,78	21,32
^{209}Po	5,53	6,39	7,05	7,75	8,45	9,16	10,21	10,77
^{208}Po	5,25	6,03	7,32	8,28	9,74	9,14	10,40	11,46

Figure 1. Preparation of microbially produced from uranium 238 (^{238} U) of different isotopes of uranium, protactinium, thorium, actinium, radium, polonium:

$$^{238}U(-\alpha)\rightarrow{}^{234}Th(-\beta)\rightarrow{}^{234}Pa(-n)\rightarrow{}^{233}Pa(-\beta)\rightarrow{}^{233}U(-2n)\rightarrow{}^{231}U(+\beta)\rightarrow{}^{231}Pa(-\alpha)\rightarrow{}^{227}Ac(-\beta)\rightarrow$$

$$\rightarrow{}^{227}Th(-n)\rightarrow{}^{226}Th(-\alpha)\rightarrow{}^{222}Ra(-\alpha)\rightarrow{}^{218}Rn(-\alpha)\rightarrow{}^{214}Po(-\alpha)\rightarrow{}^{210}Pb(-\beta)\rightarrow{}^{210}Bi(-\beta)\rightarrow{}^{210}Po$$

$$^{210}Po(-n)\rightarrow{}^{209}Po$$

$$^{210}Po(-2n)\rightarrow{}^{208}Po$$

Figure 2. Preparation of uranium-233 (^{233} U) microbially produced from uranium 238 (^{238} U) in various ways.

2-1. $^{238}U(-\alpha)\rightarrow{}^{234}Th(-\beta)\rightarrow{}^{234}Pa(-n)\rightarrow{}^{233}Pa(-\beta)\rightarrow{}^{233}U$

2-2. $^{238}U(-\alpha)\rightarrow{}^{234}Th(-\beta)\rightarrow{}^{234}Pa(-\beta)\rightarrow{}^{234}U(-n)\rightarrow{}^{233}U$

Scheme 3. Preparation of protactinium-231 (^{231} Pa) microbially produced from uranium 238 (^{238} U) in various ways.

3-1. $^{238}U(-\alpha)\rightarrow{}^{234}Th(-\beta)\rightarrow{}^{234}Pa(-n)\rightarrow{}^{233}Pa(-\beta)\rightarrow{}^{233}U(-2n)\rightarrow{}^{231}U(+\beta)\rightarrow{}^{231}Pa$

3-2. $^{238}U(-\alpha)\rightarrow{}^{234}Th(-\beta)\rightarrow{}^{234}Pa(-2n)\rightarrow{}^{232}Pa(-\beta)\rightarrow{}^{232}U(-n)\rightarrow{}^{231}U(+\beta)\rightarrow{}^{231}Pa$

Scheme 4. Preparation of thorium-230 $(^{230}$ Th) microbially produced from uranium 238 $(^{238}$ U).

$$4\text{-}1.\ {}^{238}\mathrm{U}(-\alpha)\rightarrow {}^{234}\mathrm{Th}(-\beta)\rightarrow {}^{234}\mathrm{Pa}(-\beta)\rightarrow {}^{234}\mathrm{U}(-\alpha)\rightarrow {}^{230}\mathrm{Th}$$

Next, the process stops or $(^{230}$ and excreted Th), if the thorium-230 is the ultimate goal of the process. Or, the process continues to produce valuable and rare radioactive isotopes of radium $(^{226}$ Ra), radon, astatine, polonium, bismuth, lead:

$$4\text{-}2.\ {}^{230}\mathrm{Th}(-\alpha)\rightarrow {}^{226}\mathrm{Ra}(-\alpha)\rightarrow {}^{222}\mathrm{Rn}(-\alpha)\rightarrow {}^{218}\mathrm{Po}(-\beta)\rightarrow {}^{218}\mathrm{At}(-\beta)\rightarrow {}^{218}\mathrm{Rn}(-\alpha)\rightarrow {}^{214}\mathrm{Po}(-\alpha)\rightarrow {}^{210}\mathrm{Pb}(-\beta)\rightarrow$$

$$\rightarrow {}^{210}\mathrm{Bi}(-\beta)\rightarrow {}^{210}\mathrm{Po}$$

$${}^{210}\mathrm{Po}(-n)\rightarrow {}^{209}\mathrm{Po}$$

$${}^{210}\mathrm{Po}(-2n)\rightarrow {}^{208}\mathrm{Po}$$

Scheme 5. Preparation of Actinium-227 $(^{227}$ Ac) microbially produced from uranium 238 $(^{238}$ U) in various ways.

$$5\text{-}1.\ {}^{238}\mathrm{U}(-\alpha)\rightarrow {}^{234}\mathrm{Th}(-\beta)\rightarrow {}^{234}\mathrm{Pa}(-n)\rightarrow {}^{233}\mathrm{Pa}(-\beta)\rightarrow {}^{233}\mathrm{U}(-2n)\rightarrow {}^{231}\mathrm{U}(+\beta)\rightarrow {}^{231}\mathrm{Pa}(-\alpha)\rightarrow {}^{227}\mathrm{Ac}$$

$$5\text{-}2.\ {}^{238}\mathrm{U}(-\alpha)\rightarrow {}^{234}\mathrm{Th}(-\beta)\rightarrow {}^{234}\mathrm{Pa}(-2n)\rightarrow {}^{232}\mathrm{Pa}(-\beta)\rightarrow {}^{232}\mathrm{U}(-n)\rightarrow {}^{231}\mathrm{U}(+\beta)\rightarrow {}^{231}\mathrm{Pa}(-\alpha)\rightarrow {}^{227}\mathrm{Ac}$$

Diagram 6-1. Getting Radium-226 $(^{226}$ Ra) microbiological method of uranium-238:

$${}^{238}\mathrm{U}(-\alpha)\rightarrow {}^{234}\mathrm{Th}(-\beta)\rightarrow {}^{234}\mathrm{Pa}(-\beta)\rightarrow {}^{234}\mathrm{U}(-\alpha)\rightarrow {}^{230}\mathrm{Th}(-\alpha \rightarrow {}^{226}\mathrm{Ra}$$

Scheme 7. Preparation of the most valuable and stable isotopes of polonium $(^{210}$ Po, ^{209} Po, ^{208} Po) microbially produced from uranium 238 $(^{238}$ U).

$$7\text{-}1.\ {}^{238}\mathrm{U}(-\alpha)\rightarrow {}^{234}\mathrm{Th}(-\beta)\rightarrow {}^{234}\mathrm{Pa}(-n)\rightarrow {}^{233}\mathrm{Pa}(-\beta)\rightarrow {}^{233}\mathrm{U}(-2n)\rightarrow {}^{231}\mathrm{U}(+\beta)\rightarrow {}^{231}\mathrm{Pa}(-\alpha)\rightarrow$$

$$\rightarrow {}^{227}\mathrm{Ac}(-\beta)\rightarrow {}^{227}\mathrm{Th}(-n)\rightarrow {}^{226}\mathrm{Th}(-\alpha)\rightarrow {}^{222}\mathrm{Ra}(-\alpha)\rightarrow {}^{218}\mathrm{Rn}(-\alpha)\rightarrow {}^{214}\mathrm{Po}(-\alpha)\rightarrow {}^{210}\mathrm{Pb}(-\beta)\rightarrow$$

$$\rightarrow {}^{210}\mathrm{Bi}(-\beta)\rightarrow {}^{210}\mathrm{Po}$$

$${}^{210}\mathrm{Po}(-n)\rightarrow {}^{209}\mathrm{Po}$$

$${}^{210}\mathrm{Po}(-2n)\rightarrow {}^{208}\mathrm{Po}$$

$$7\text{-}2.\ {}^{238}\mathrm{U}(-\alpha)\rightarrow {}^{234}\mathrm{Th}(-\beta)\rightarrow {}^{234}\mathrm{Pa}(-2n)\rightarrow {}^{232}\mathrm{Pa}(-\beta)\rightarrow {}^{232}\mathrm{U}(-n)\rightarrow {}^{231}\mathrm{U}(+\beta)\rightarrow {}^{231}\mathrm{Pa}(-\alpha)\rightarrow {}^{227}\mathrm{Ac}\rightarrow$$

further transformation path elements and isotopes ^{210} Po, ^{209} Po, ^{208} Po is identical to the scheme 7-1.

$$7\text{-}3.\ {}^{238}\mathrm{U}(-\alpha)\rightarrow {}^{234}\mathrm{Th}(-\beta)\rightarrow {}^{234}\mathrm{Pa}(-\beta)\rightarrow {}^{234}\mathrm{U}(-n)\rightarrow {}^{233}\mathrm{U}(-\alpha)\rightarrow {}^{229}\mathrm{Th}(-\alpha)\rightarrow {}^{225}\mathrm{Ra}(-\beta)\rightarrow$$

$$\rightarrow {}^{225}\mathrm{Ac}(-n)\rightarrow {}^{224}\mathrm{Ac}(+\beta)\rightarrow {}^{224}\mathrm{Ra}(-\alpha)\rightarrow {}^{220}\mathrm{Rn}(-\alpha)\rightarrow {}^{216}\mathrm{Po}(-\alpha)\rightarrow {}^{212}\mathrm{Pb}(-\beta)\rightarrow {}^{212}\mathrm{Bi}(-n)\rightarrow {}^{211}\mathrm{Bi}(-\beta)\rightarrow$$

$$\rightarrow {}^{211}\mathrm{Po}(-n)\rightarrow {}^{210}\mathrm{Po}$$

$${}^{211}\mathrm{Po}(-2n)\rightarrow {}^{209}\mathrm{Po}$$

Example 3.

The method of the process is the same as in Example 1. The chemical transmutation and producing new elements and isotopes in the feedstock used for the microbial treatment Jordan uranium ore containing elements uranium, thorium, phosphorus, arsenic, iron, vanadium in an oxidized form (phosphates, arsenates, vanadates), and in a reduced form.

Therefore, to create a high redox potential feedstock treated microorganisms Thiobacillus halophilus strain DSM-6132 in an aqueous solution with a variable valence elements having redox $^{\text{ability:}}$ Rb +1, Sr +2, S $^{0\,/}$ S -2, Re +4 / Re $^{+7,\ +3}$ As / As $^{+5,\ +4}$ Mn / Mn $^{+7,}$ Fe $^{+2}$ / Fe $^{+3,\ -3}$ N / N $^{+5,\ +5}$ P, S $^{-2}$ / S in their common $^{+6}$ weight 0.01% by weight of the medium.

The redox potential (Eh) of the solution in the logarithmic transmutation process step is 753 mV. The temperature of the process of 28-32 degrees Celsius, pH 2.0-2.5 environment. The time of the twenty-day process.

The results of these experiments and statistically processed according to the process of time are shown in Table 3. The spectrograms analysis of chemical elements in transmutation microbiological Jordan uranium ore processing, depending on the time of the process, after 24 hours (1 day), 120 hours (five days) through 192 hours (8 days), are shown in figures 12, 13, 14, respectively.

Элементы	Период полу-распада $T_{1/2}$	Содержание элементов в 100 г руды, мг	Количество мг элементов в 1 литре раствора н мг элемента/100 г руды в 1 л раствор (Руда Иордании, массовая доля ^{238}U=387					
			Сутки					
			1	2	3	4	5	6
^{238}U	4,5x10^9 , Лет	38,78	38,78	27,25	10,75	2,62	0	0
^{234}Th	24,1 суток	0	0	6,87	10,38	7,37	0	0
^{234}Pa	6,66 час	0	0	4,48	1,16	0	0	0
^{233}Pa	27 сут.	0	0	0	2,00	2,25	2,32	0
^{232}Pa	1,31 суток	0	0	0	3,41	4,14	1,25	0
^{231}Pa	3,43 x 10^4 лет	0	0	0	0	6,37	12,64	17,74
^{234}U	2 x10^{16} лет	0	0	0	5,71	6.28	4,16	3,97
^{233}U	1,62 x 10^5 лет	0	0	0	4,77	4,95	3,83	0
^{232}U	8x10^{13} лет, 74г	0	0	0	0	2,84	3,03	0
^{227}Ac	21,6 год	0	0	0	0	0	9,80	10,32
^{230}Th	8 x 10^4 лет	0	0	0	0	1,09	0	0
^{226}Ra	1617 г	0	0	0	0	0	0,37	0,42
^{210}Po	138,4 суток	0	0	0	0	0	0	0,72
^{209}Po	103 г	0	0	0	0	0	0	0,49
^{208}Po	2,93 г	0	0	0	0	0	0	0,27

Таблица 3. Результаты трансмутации химических элементов и превращения изотопов в процессе микробио урановой руды Иордании.

Scheme 3. Preparation of protactinium-231 (^{231} Pa) microbially produced from uranium 238 (^{238} U) in various ways.

3-1. $^{238}U(-\alpha) \rightarrow {}^{234}Th(-\beta) \rightarrow {}^{234}Pa(-n) \rightarrow {}^{233}Pa(-\beta) \rightarrow {}^{233}U(-2n) \rightarrow {}^{231}U(+\beta) \rightarrow {}^{231}Pa$

3-2. $^{238}U(-\alpha) \rightarrow {}^{234}Th(-\beta) \rightarrow {}^{234}Pa(-2n) \rightarrow {}^{232}Pa(-\beta) \rightarrow {}^{232}U(-n) \rightarrow {}^{231}U(+\beta) \rightarrow {}^{231}Pa$

Scheme 4. Preparation of thorium-230 (^{230} Th) microbially produced from uranium 238 (^{238} U).

4-1. $^{238}U(-\alpha) \rightarrow {}^{234}Th(-\beta) \rightarrow {}^{234}Pa(-\beta) \rightarrow {}^{234}U(-\alpha) \rightarrow {}^{230}Th$

Next, the process stops or (^{230} and excreted Th), if the thorium-230 is the ultimate goal of the process. Or, the process continues to produce valuable and rare radioactive isotopes of radium (^{226} Ra), radon, astatine, polonium, bismuth, lead:

$$4\text{-}2.\ {}^{230}Th(-\alpha)\rightarrow{}^{226}Ra(-\alpha)\rightarrow{}^{222}Rn(-\alpha)\rightarrow{}^{218}Po(-\beta)\rightarrow{}^{218}At(-\beta)\rightarrow{}^{218}Rn(-\alpha)\rightarrow{}^{214}Po(-\alpha)\rightarrow{}^{210}Pb(-\beta)\rightarrow$$

$$\rightarrow{}^{210}Bi(-\beta)\rightarrow{}^{210}Po$$

$${}^{210}Po(-n)\rightarrow{}^{209}Po$$

$${}^{210}Po(-2n)\rightarrow{}^{208}Po$$

Scheme 5. Preparation of Actinium-227 (^{227} Ac) microbially produced from uranium 238 (^{238} U) in various ways.

$$5\text{-}1.\ {}^{238}U(-\alpha)\rightarrow{}^{234}Th(-\beta)\rightarrow{}^{234}Pa(-n)\rightarrow{}^{233}Pa(-\beta)\rightarrow{}^{233}U(-2n)\rightarrow{}^{231}U(+\beta)\rightarrow{}^{231}Pa(-\alpha)\rightarrow{}^{227}Ac$$

$$5\text{-}2.\ {}^{238}U(-\alpha)\rightarrow{}^{234}Th(-\beta)\rightarrow{}^{234}Pa(-2n)\rightarrow{}^{232}Pa(-\beta)\rightarrow{}^{232}U(-n)\rightarrow{}^{231}U(+\beta)\rightarrow{}^{231}Pa(-\alpha)\rightarrow{}^{227}Ac$$

Diagram 6-1. Getting Radium-226 (^{226} Ra) microbiological method of uranium-238:

$${}^{238}U(-\alpha)\rightarrow{}^{234}Th(-\beta)\rightarrow{}^{234}Pa(-\beta)\rightarrow{}^{234}U(-\alpha)\rightarrow{}^{230}Th(-\alpha\rightarrow{}^{226}Ra$$

Scheme 7. Preparation of the most valuable and stable isotopes of polonium (^{210} Po, ^{209} Po, ^{208} Po) microbially produced from uranium 238 (^{238} U).

$$7\text{-}1.\ {}^{238}U(-\alpha)\rightarrow{}^{234}Th(-\beta)\rightarrow{}^{234}Pa(-n)\rightarrow{}^{233}Pa(-\beta)\rightarrow{}^{233}U(-2n)\rightarrow{}^{231}U(+\beta)\rightarrow{}^{231}Pa(-\alpha)\rightarrow$$

$$\rightarrow{}^{227}Ac(-\beta)\rightarrow{}^{227}Th(-n)\rightarrow{}^{226}Th(-\alpha)\rightarrow{}^{222}Ra(-\alpha)\rightarrow{}^{218}Rn(-\alpha)\rightarrow{}^{214}Po(-\alpha)\rightarrow{}^{210}Pb(-\beta)\rightarrow$$

$$\rightarrow{}^{210}Bi(-\beta)\rightarrow{}^{210}Po$$

$${}^{210}Po(-n)\rightarrow{}^{209}Po$$

$${}^{210}Po(-2n)\rightarrow{}^{208}Po$$

$$7\text{-}2.\quad {}^{238}U(-\alpha)\rightarrow{}^{234}Th(-\beta)\rightarrow{}^{234}Pa(-2n)\rightarrow{}^{232}Pa(-\beta)\rightarrow{}^{232}U(-n)\rightarrow{}^{231}U(+\beta)\rightarrow{}^{231}Pa(-\alpha)\rightarrow{}^{227}Ac\rightarrow$$

далее путь превращений элементов и изотопов до ^{210}Po,^{209}Po,^{208}Po идентичен схеме 7-1.

$$7\text{-}3.\ {}^{238}U(-\alpha)\rightarrow{}^{234}Th(-\beta)\rightarrow{}^{234}Pa(-\beta)\rightarrow{}^{234}U(-n)\rightarrow{}^{233}U(-\alpha)\rightarrow{}^{229}Th(-\alpha)\rightarrow{}^{225}Ra(-\beta)\rightarrow$$

$$\rightarrow{}^{225}Ac(-n)\rightarrow{}^{224}Ac(+\beta)\rightarrow{}^{224}Ra(-\alpha)\rightarrow{}^{220}Rn(-\alpha)\rightarrow{}^{216}Po(-\alpha)\rightarrow{}^{212}Pb(-\beta)\rightarrow{}^{212}Bi(-n)\rightarrow{}^{211}Bi(-\beta)\rightarrow$$

$$\rightarrow{}^{211}Po(-n)\rightarrow{}^{210}Po$$

$${}^{211}Po(-2n)\rightarrow{}^{209}Po$$

Example 4.

The method of the process is the same as in Example 1. The chemical transmutation and producing new elements and isotopes in the feedstock used for the microbial treatment monazite sand containing thorium Indian ocean coast, comprising elements thorium, phosphorus, arsenic, silicon, aluminum, and cerium and other lanthanides, and mainly in the reduced form.

Therefore, to create a high redox potential feedstock treated microorganisms Thiobacillus ferrooxidans strain DSM-14882 in an aqueous solution with a variable valence elements, in solution in the oxidized form: $^{+5}$ N, P $^{+5,}$ As $^{+5,\ +6}$ S, Fe $^{+3,}$ Mn +7, their total weight 0.01% by weight of the medium.

The redox potential (Eh) of the solution in the logarithmic transmutation process step is 717 mV. The temperature of the process of 28-32 degrees Celsius, pH 1.0-1.5 environment. The timing of the process for ten days.

The results of these experiments and statistically processed according to the process of time are shown in Table 4. The spectrograms analysis of chemical elements in transmutation microbiological treatment thorium containing sand Indian ocean coast, depending on the time of the process, after 24 hours (1 day), 120 hours (five days) after 240 hours (ten days) are shown in figures 15, 16, 17, respectively.

Элементы	Содержание элементов в 100 г руды, мг	Количество мг элементов в 1 литре раствора на 100 мг элемента/100 г руды в 1 л раствора. (монацитовый песок побережья Индийского океана, массовая дол						
		Сутки						
		1	2	3	4	5	6	7
^{232}Th	44	44	42,4	33,92	20,88	17,08	8,80	6,08
^{228}Ra	0	0	1,57	3,18	4,37	6,00	4,00	2,93
^{227}Ac	0	0	0	6,71	18,33	16,62	25,60	28,03
^{210}Po	0	0	0	0	0	3,33	3,30	2,53
^{209}Po	0	0	0	0	0	0	0,27	0,83
^{208}Po	0	0		0	0	0	0	1,22
	0						0	0,53
	0						0	0

Таблица 4. Результаты трансмутации химических элементов и превращения изотопов в процессе микро(
монацитового торий-содержащего песка побережья Индийского океана.

Diagram 6-2. Preparation of radium-228 (^{228} Ra) microbially produced from natural thorium-232: $^{232}Th(-\alpha)\rightarrow\ ^{228}Ra$

Figure 8. Production of various isotopes of thorium, actinium, radium, polonium microbially produced from natural thorium-232 (^{232} Th):

$$^{232}Th(-\alpha)\rightarrow ^{228}Ra(-\beta)\rightarrow ^{228}Ac(-n)\rightarrow ^{227}Ac(-\beta)\rightarrow ^{227}Th(-n)\rightarrow ^{226}Th(-\alpha)\rightarrow ^{222}Ra(-\alpha)\rightarrow ^{218}Rn(-\alpha)\rightarrow$$

$$\rightarrow ^{214}Po(-\alpha)\rightarrow ^{210}Pb\ (-\beta)\rightarrow ^{210}Bi\ (-\beta)\rightarrow ^{210}Po$$

$$^{210}Po(-n)\rightarrow ^{209}Po$$

$$^{210}Po(-2n)\rightarrow ^{208}Po$$

Example 5.

The method of the process is the same as in Example 1. The chemical transmutation and producing new elements and isotopes in the feedstock used for the microbial treatment of polonium-209, obtained in our process of actinides turning (decays) in more isotopes of mercury, gold and platinum (scheme 10). Raw treated microorganisms Thiobacillus aquaesulis strain DSM-4255 in an aqueous solution with a variable valence elements having redox $^{ability:}$Rb +1, Sr +2, S ^{0} / S $^{-2,\ +4}$ Re / Re $^{+7,}$ As $^{+3}$ / As $^{+5,\ +4}$ Mn / Mn $^{+7,}$ Fe $^{+2}$ / Fe $^{+3,\ -3}$ N / N $^{+5,}$ P $^{+5,\ -2}$ S / S $^{+6}$ in their total weight 0.01% by weight of the . The redox potential (Eh) of the solution in the logarithmic transmutation process step is 698 mV. The temperature of the process of 28-32 degrees Celsius, pH 2.0-2.5 environment. The time of the twenty-day process.

Based on the experimental and statistical data processed by the authors derived the following scheme:

Scheme 10. Preparation of stable isotopes of mercury and gold $(^{197}$ Au) microbiological method to initiate and accelerate the reaction of the polonium-209 $(^{209}$ Po):

$^{209}Po(+\beta)\rightarrow{}^{209}Bi(-\breve{a})\rightarrow{}^{205}Tl$ (бакт. захват -α)→ $^{201}Au(-\beta, T_{1/2}$=26мин.)→ $^{201}Hg(-n)\rightarrow{}^{200}Hg$

$^{201}Hg(-2n)\rightarrow{}^{199}Hg$

$^{201}Hg(-\breve{a})\rightarrow{}^{197}Pt\ (-\beta, T_{1/2}$ = 17,4 часов и 88 минут)→ ^{197}Au, единственный стабильный изотоп золота из известных.

Example 6.

The method of the process is the same as in Example 1. The chemical transmutation and producing new elements and isotopes in the feedstock used for the microbial treatment of polonium-208, obtained in our process of actinides turning (decays) in more isotopes of mercury, gold and platinum (scheme 11).

Raw treated microorganisms Thiobacillus ferrooxidans strain DSM-14882 in an aqueous solution with a variable valence elements having redox $^{ability:}$Rb +1, Sr +2, S ^{0} / S $^{-2,\ +4}$ Re / Re $^{+7,}$ As $^{+3}$ / As $^{+5,\ +4}$ Mn / Mn $^{+7,}$ Fe $^{+2}$ / Fe $^{+3,\ -3}$ N / N $^{+5,}$ P $^{+5,\ -2}$ S / S $^{+6}$ in their total weight 0.01% by weight of the transmutation process solution in the logarithmic stage Eh = 753 mV. The microorganisms employed temperature of the process of 28-32 degrees Celsius, pH 1.0-1.5 environment. The time of the twenty-day process. Based on the experimental and statistical data processed by the authors derived the following scheme:

Scheme 11. Preparation of stable isotopes of mercury, thallium, platinum $(^{195}$ Pt) and gold $(^{197}$ Au) microbiological method to initiate and accelerate the reaction of the polonium-208:

$^{208}Po(+\beta)\rightarrow{}^{208}Bi(-\breve{a})\rightarrow{}^{204}Tl(+\beta,\ -\beta,\ T_{1/2}$=3,56 лет)→бактериальное инициирование и ускорение:

11-1. $^{204}Tl(+\beta)\rightarrow{}^{204}Hg(-n)\rightarrow{}^{203}Hg(-\beta)\rightarrow{}^{203}Tl(+\beta)\rightarrow{}^{203}Hg(-\beta)\rightarrow{}^{203}Tl(-n)\rightarrow{}^{202}Tl(+\beta)\rightarrow$
$\rightarrow{}^{202}Hg(-n)\rightarrow{}^{201}Hg$

$^{202}Hg(-2n)\rightarrow{}^{200}Hg$.

$^{202}Hg(-\breve{a})\rightarrow{}^{198}Pt$ (стабильный изотоп платины).

11-2. $^{204}Tl(+\beta)\rightarrow{}^{204}Hg(-n)\rightarrow{}^{203}Hg(-\beta)\rightarrow{}^{203}Tl(-\breve{a})\rightarrow{}^{199}Au(-\beta, T_{1/2}$=3,14 суток)→
$\rightarrow{}^{199}Hg(-n)\rightarrow{}^{198}Hg$

$^{199}Hg(-2n)\rightarrow{}^{197}Hg(+\beta, T_{1/2}$ = 65 часов и 24 часа)→ ^{197}Au (единственный стабильный изотоп золота из известных).

$^{199}Hg(-\breve{a})\rightarrow{}^{195}Pt$ (стабильный изотоп платины).

11-3. $^{204}Tl(-\beta)\rightarrow{}^{204}Pb(-n)\rightarrow{}^{203}Pb(+\beta)\rightarrow{}^{203}Tl(-2n)\rightarrow{}^{201}Tl(+\beta,T_{1/2}$=72ч, 5мс)→ $^{201}Hg(-n)\rightarrow{}^{200}Hg$

$^{201}Hg(-2n)\rightarrow{}^{199}Hg$

$^{201}Hg(-\breve{a})\rightarrow{}^{197}Pt\ (-\beta, T_{1/2}$ = 17,4 часов и 88 минут)→ ^{197}Au (единственный стабильный изотоп золота из известных).

Example 7.

The method of the process is the same as in Example 1. The chemical transmutation and producing new elements and isotopes in the feedstock used for the microbial treatment of plutonium samples to convert the plutonium-239 in U-235, protactinium-231 and actinium-227 (scheme 12) was treated with microorganisms.

Syre Thiobacillus thioparus strain DSM-505 in aqueous solution with a variable valence elements having redox $^{ability:}$ Rb +1, Sr +2, S^{0} / $S^{-2, +4}$ Re / $Re^{+7, +3}$ As / $As^{+5, +4}$ Mn / $Mn^{+7,}$ Fe^{+2} / $Fe^{+3, -3}$ N / $N^{+5,}$ $P^{+5, -2}$ S / S^{+6} in their total weight 0.01 % by weight of the medium. The redox potential (Eh) of the solution in the process of transmutation logarithmic stage of the process of transmutation Eh = 759 mV.

The temperature of the process of 28-32 degrees Celsius, pH 2.0-2.5 environment. The time of the twenty-day process. Based on the experimental and statistical data processed by the authors derived the following scheme:

Scheme 12. Preparation of uranium-235, thorium-231, protactinium-231 and actinium-227 microbiological method with the acceleration of plutonium-239 decay reactions (may use weapons-grade plutonium, or plutonium - a byproduct of the combustion of nuclear fuel rods NPP to be waste):

$$^{239}Pu(-\alpha)\rightarrow {}^{235}U(-\alpha)\rightarrow {}^{231}Th(-\beta)\rightarrow {}^{231}Pa(-\alpha)\rightarrow {}^{227}Ac.$$

It is possible to stop the process at any stage, to obtain ^{235} U, ^{231} or Th, or ^{231} Pa, and ^{227} Ac, or mixtures thereof in various proportions. Or, you can continue the process of transformation of elements and isotopes of actinium-227 to^{210,} the Po, the Po $^{209, 208}$ the Po, to give the intermediate elements, according to the scheme 7-1.

Example 8.

The method of the process is the same as in Example 1. The chemical transmutation and producing new elements and isotopes in the feedstock used for the microbial treatment of plutonium samples to convert the plutonium-241, americium-241 and Np-237 (Scheme 13). ^{241} Pu - a byproduct of nuclear reactions at nuclear power plants burning fuel elements, subject to utilization, taken as a nuclear waste and industrial by-product of uranium combustion.

Raw treated microorganisms Thiobacillus tepidarius strain DSM-3134 in an aqueous solution with a variable valence elements having redox $^{ability:}$ Rb +1, Sr +2, S^{0} / $S^{-2, +4}$ Re / $Re^{+7,}$ As^{+3} / $As^{+5, +4}$ Mn / $Mn^{+7,}$ Fe^{+2} / $Fe^{+3, -3}$ N / $N^{+5,}$ $P^{+5, -2}$ S / S^{+6} in their total weight 0.01% by weight of the . Eh = 736 mV. The temperature of the process of 28-32 degrees Celsius, pH 2.0-2.5 environment.

Scheme 13. Preparation of americium-241 $^{(241}$ Am) and neptunium-237 $^{(237}$ Np) microbiological method of plutonium-241, with the initiation and acceleration of decomposition reactions:

^{241}Pu (-β, $T_{1/2}$ = 13 лет; бактериальная инициация и ускорение)→ ^{241}Am(-α, $T_{1/2}$=2 x 10^{14} лет и 485 лет; бактериальная инициация и ускорение)→ ^{237}Np (-α, $T_{1/2}$ = 2,2 x 10^{5} лет).

.

The process can be stopped or slowed down at the stage of americium-241 with the selection of the latter.

Example 9.

This example shows the intensification of the process of transmutation of chemical elements in its deceleration when the limiting factors. The method of the process and raw materials are the same as in Example 2.

The control variant: As raw material was used as a uranium ore North-West Africa, but unlike Example 2 consisted ore more content in the solution: solid ratio (ore) to the liquid phase was 1: 3 (100 grams of ore per 300 ml of aqueous solution).

Raw treated microorganisms Thiobacillus aquaesulis strain DSM-4255 in an aqueous solution with a variable valence elements, in solution in the oxidized $^{form:}$ N +5, P +5 (in the form of phosphate), As $^{+5, +6}$ S, Fe $^{+3,}$ Mn ^{7,} a total weight of 0.01% by weight of the medium, as in example 2. Eh = 410 mV.

The temperature of the process to 30-35 degrees Celsius, pH 2.0-2.5 of the medium. The time of the twenty-day process. The charge of bacteria close to zero. The electrophoretic mobility (EPM) of microbial cells is equal to $^{0{,}01}$ V -1 × cm ^{2} × s $^{-1.}$

The initial uranium-238 content in the medium was 280 g / l. On the fifth day of the process the uranium-238 content dropped to 200.52 mg / L, but protactinium-231, actinium-227 and polonium isotopes were detected in the medium, wherein the detected isotopes thorium-234, protactinium, 234, 233, protactinium, uranium -234 (primary products of transmutation of uranium-238).

Transmutation process, and uranium-238 cells and formation of new isotopes were retarded in time in comparison with Example 2, in which the solid phase ratio (ore) to the liquid phase was 1:10 (100 grams of ore per 1000 ml aqueous solution). Slowing the process due to the high concentration of metal ions in the solution with a small amount of water to the ore.

Experimental variant: The same solution is limited by the water in which the solid phase ratio (ore) to the liquid phase is 1: 3 (100 grams of ore per 300 ml of aqueous solution) was further introduced 0,001 g / l polyampholyte - polyacrylic acid, caprolactam (the ratio of acrylic acid to caprolactam 9: 1). The electrophoretic mobility (EPM) of microbial cells is equal to $^{0{,}89}$ V -1 × cm ^{2} × s $^{-1,}$ microorganisms charge moved from the isoelectric point in the negative direction. Eh = 792 mV On the fifth day content in uranium-238 solution was equal to 149.40 mg / L, there were isotopes - products of further decay: uranium-232, uranium-233, protactinium-231, Actinium-227, radium-226, polonium -210, 209 and 208 - all in large quantities.

There has been a process of acceleration. On the basis of experimental data, a general overview of the various areas and uranium-238 decay chains being formed into a microbiological method of different isotopes of uranium, protactinium, thorium, actinium, radium, polonium and other elements (Figure 18).

Electronic transition energy (keV), which was determined by chemical elements by X-ray fluorescence (Figures 1 to 17) are shown in Table 5.

Таблица 5. Значения энергии электронного перехода (keV)

Элементы	keV								
	$L_{\alpha 1}$	$L_{\alpha 2}$	$L_{\alpha 3}$	$L_{\alpha 4}$	$L_{\beta 1}$	$L_{\beta 2}$	$K_{\alpha 1}$	$K_{\alpha 2}$	$K_{\beta 1}$
Am	14,62	14,41			18,86				
Pu	14,28	14,09			18,30				
Np	13,95	13,76			17,75				
U	13,61	13,44					14,40	11,62	
Pa	13,29	13,12			16,70	15,99			
Th	12,97	12,81			16,20				
Ac	12,65	12,50			15,71				
Ra	12,34	12,20			15,24				
Fr	12,03	11,90			14,77				
Po	11,13	11,016			13,45				
Hg	9,99				1,82				
Au	9,71	9,63			11,44				
Pt	9,44	9,36			11,07				
Hf	7,90	7,84			9,02				
Yb	7,42	7,37			8,40				
Zr							15,77	15,69	17,67
Y							14,96		16,70
Sr							14,16	14,10	15,83
Rb							13,40	13,34	14,96
Br							11,92	11,88	13,29
As							10,54		11,73
Ga							9,25		10,27
Ni							7,48		8,27
Fe							6,40		7,06

1. Microbiological method transmutation chemical conversion elements and isotopes of chemical elements, characterized in that the radioactive feedstock containing radioactive chemical elements or isotopes, treated with an aqueous suspension of bacteria of the genus Thiobacillus, in the presence of variable valence elements.
2. A method according to claim 1, characterized in that the process leads to obtain polonium, radon, France, radium, actinium, thorium, protactinium, uranium, neptunium, americium, nickel, manganese, bromine, hafnium, ytterbium, mercury, gold, platinum and their isotopes.
3. The method of claim 1 or 2, characterized in that as a radioactive materials containing radioactive chemical elements or radioactive ore used nuclear waste cycles.