

## Low Energy Transmutation of Atomic Nuclei of Chemical Elements

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**ABSTRACT.** A short review of experimental results indicative of the existence of a forbidden physical phenomenon – a transformation of some atomic nuclei into other atomic nuclei at low energies - is given. As this takes place, no gamma-ray quanta, neutrons, and beta particles accompanying such nuclear transformations were found. The amplitude of the impact of such transmutation achieves a value of  $\sim 10^{-2}$ . The results of our check experiments on low energy element transmutation and a calculation of possible end products that are yielded in this process under consideration of energy balances of nuclear reactions are shown. Three mechanisms of prohibition of transmutation phenomenon within modern physical conceptions are indicated. The conclusion is drawn that a sole possibility to match these prohibitions with the observed transmutation processes consists in increasing the reaction domain up to atomic dimensions.

**RESUME.** On donne un bref aperçu des résultats expérimentaux indiquant l'existence d'un phénomène physique interdit- la transformation des noyaux atomiques d'uns éléments chimiques en d'autres sous l'action des basses énergies. Dans ces transformations il n'apparaît pas, de rayon-X gamma, de neutrons et de particules bêta. L'amplitude de l'effet d'une telle transmutation est de l'ordre de grandeur de  $10^{-2}$ . On donne les résultats de nos expériences de contrôle de la transmutation de basse énergétique des éléments et le décompte des produits possibles finaux résultant dans ce processus qui donne la balance énergétique des réactions nucléaires. Trois mécanismes de la transmutation actuellement supposée interdite sont proposés. On en tire la conclusion que la seule possibilité pour rendre compte de ces interdictions et des transmutations observées est d'étendre le domaine de réaction jusqu'aux dimensions atomiques.

## Introduction

At the present time, information about new physical phenomenon – low energy transmutation of atomic nuclei of chemical elements - has appeared in literature and private communications. In particular, low energy element transmutation (LEET) is seen at electric explosion of metal foils in a liquid dielectric medium, at electron-beam melting of zirconium ingots in a vacuum furnace and at ultrasound processing of aqueous salt solutions.

The purpose of the present work is to carry out (at the JINR, Dubna, Russia) a comparative analysis of literature data on LEET phenomenon, to represent results of our check experiments on foils electric explosion, to calculate possible final products of transmutation under consideration of energy balances of nuclear reactions.

### 1 Short summary

In this review we represent the already published works on experimental observing of the phenomenon of low energy element transmutation leaving without consideration those works which may be known to us but which are not published yet. Furthermore, we represent experimental data, which have been just obtained by the authors, reasoning that authors' interpretation and description of physical processes causing the phenomenon of low energy element transmutation should also not be included in the present paper. Realizing that publications on the topic under discussion are not easily accessible for a broad circle of readers we give short descriptions of experimental installations at which the transmutation phenomenon was discovered.

#### *1.1 Experiments on electric explosion of metallic foils in liquid media*

Those experiments were carried out at the Russian Research Center "Kurchatov Institute" under the direction of L.I.Urutskov [1]. The experimental installation represents an explosion cell made in the form of polyethylene torus with eight holes which are uniformly drilled along the circle. Polyethylene cups filled with distilled water are insert into the holes. Titanium electrodes are put into the cups, metallic foils, which are a load, were connected by contact electric welding to the electrodes. The cup diagram of the explosion cell is given in Fig.1. Metallic foils of titanium and zirconium were used as loads. Electrodes with loads were located on the polyethylene cap, which seals the explosion cell. Electrodes lead out on the external surface of the cap were connected to capacitor bank. Energy storage of the bank at discharge voltage  $U \sim 4$  kV was equal to  $W \sim 50$  kJ. At pulse supply of the voltage to explosion cell, metallic foils were destroyed (electric explosion).

The duration of current pulse in experiments was 150  $\mu\text{s}$  with characteristic current pulse growth times  $\sim 10 \mu\text{s}$ . The authors of the paper affirm that, besides a main element and its admixtures, atoms of other elements are formed in the products of electric explosion, which were not present in the explosion volume prior to beginning of the process. The content of foreign elements in the electric explosion products attains several percent of the

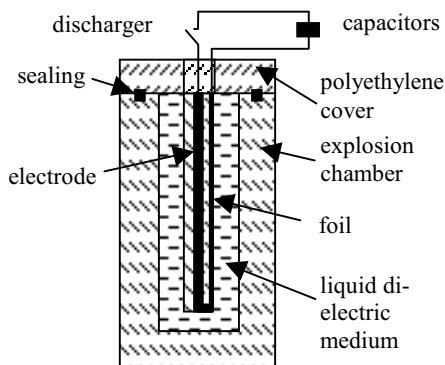


Fig.1. Diagram of experimental installation.

amount of atoms of the main foil element, what corresponds to  $\sim 10^{17} \div 10^{18}$  atoms. The list of foreign elements includes: B, Na, Mg, Al, Si, Ca, V, Cr, Fe, Ni, Cu, Zn, Ba, Pb. The authors note that a particular spectrum of foreign chemical elements corresponds to various initial loads (Ti, Zr). Element composition of all parts of explosion cells was investigated by various techniques before the explosion. The authors also report a change in the isotope composition of titanium, in particular, a diminished specific quantity of  $^{48}\text{Ti}$ . Experiments show a correlation between a percentage of foreign elements and a decreased proportion of  $^{48}\text{Ti}$ . The paper was based on results of more than 200 experiments. At this point, over 1000 such experiments have been carried out. Therein, the element transmutation phenomenon is observed steadily. Furthermore, the authors registered some "strange" particles in their experiments, accompanying the transmutation effect, and hypothesized the presence of magnetic charge in those particles.

### 1.2 Experiments on electron beam melting of zirconium in vacuum

The paper by M.I.Solin [2] describes the results of experiments on electron-beam melting of zirconium ingots. Standard industrial vacuum furnaces

with electron-beam heating of the ingot were used for the tests. Electron gun accelerating voltage was kept at a level 30 keV. The density of power applied to the surface of liquid bath on zirconium surface amounted to  $0.38 - 0.4 \text{ kW/cm}^2$ . The paper describes some phenomena that appear in the process of electron-beam vacuum melting of zirconium. We just mention that melting of zirconium was accompanied in those experiments by intense oscillation hydrodynamic processes and we dwell on the data on foreign elements formation in zirconium ingots during the melting. After melting, the zirconium ingots show microstructures or, as the author calls them, nugget products, whose element composition differs substantially from initial material (Fig.2). As you can see the nugget product shows the formation of Li, Be, B, Ba and rare earth metals, i.e. elements that were absent in the initial ingot. Furthermore, the content of such elements as Na, Mg, Al, Si, K, Ca, Ti, Cr, Mn, Fe in the obtained nugget product has increased (by 2-3 orders of magnitude). The content of these elements in some zones amounts to 2 to 45 mass percent.

The author reported a significant, 6-8 times, increasing of the rate of ingot melting at a constant applied energy of electron beam, and for some modes of ingot heating, this value has increased by 50 times. As this takes place, the ingot mass is a critical parameter for initiating abnormal processes.

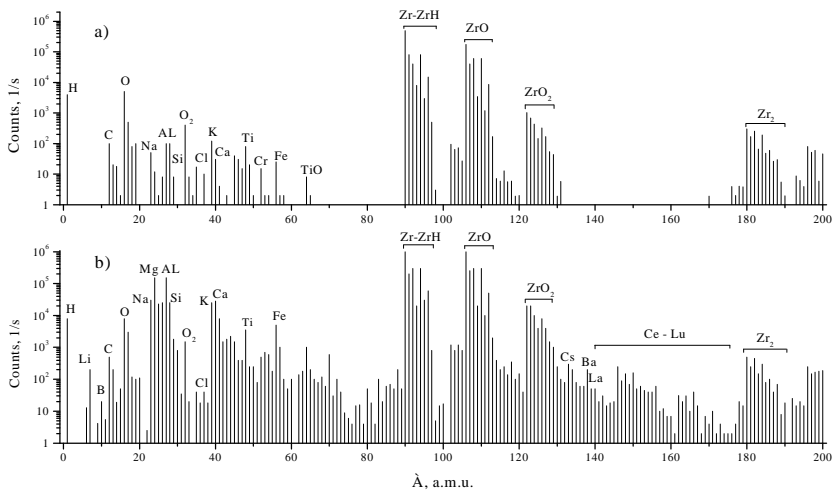


Fig. 2. a) mass spectrum of zirconium ingot prior to electron melting; b) mass spectrum of microstructure in zirconium ingot after electron melting

1.3 Ultrasound element transmutation

Destruction (transmutation) of atomic nuclei of chemical compounds is noted in the works by A.Kladov [3-5], including radioactive isotopes, after ultrasound treatment of their aqueous solutions. Main results of these experiments were taken from [6]. The experimental installation represents an ultrasonic hydrodynamic generator of rotor type. The activator is made from stainless steel. The installation has the following main parameters: sound intensity  $>10^6$  W/m<sup>2</sup>, frequency (fundamental tone) -  $5.9 \cdot 10^3$  Hz, operating pressure in activator -  $10^6$  Pa, working volume -  $6.3 \cdot 10^{-3}$  m<sup>3</sup>, active zone volume -  $0.25 \cdot 10^{-3}$  m<sup>3</sup>.

The author dealt with stable and radioactive isotopes. In case of stable elements, initial solutions were treated during 2, 8, 24 hours for LiCl and 360 hours for CsCl. Element spectra, obtained for various solution treatment times of stable elements, are presented in Fig.3. You can see from the figure that a quantity of foreign elements, from boron to lead (Fig.3c), actually

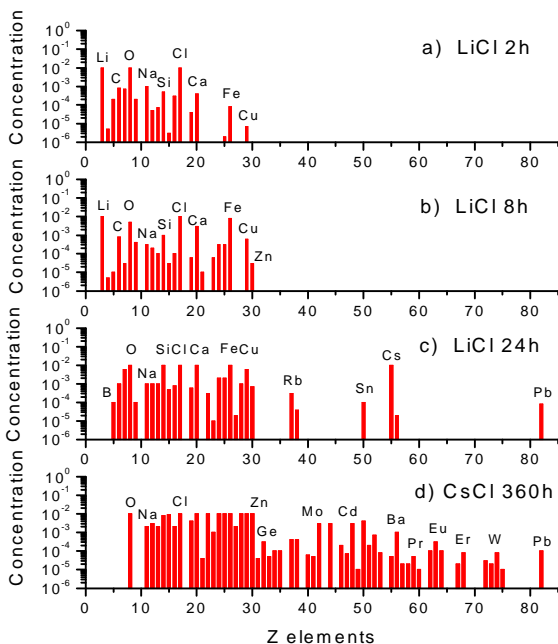


Fig. 3. Element composition of lithium chloride solution after ultrasonic activation: a) 2-hour, b) 8-hour, c) 24-hour, d) element composition of caesium chloride solution after 360-hour ultrasonic activation.

increases in solution as time goes on. Unfortunately, the author did not show in his paper the element composition of LiCl and CsCl salt solutions prior to ultrasonic activation. However, we can do an indirect background evaluation by spectra comparison of LiCl after 2- and 24-hour treatment. It should be noted that, at the element solution analysis, the saturation is observed for many elements at a concentration of  $10^{-2}$ , it is likely to be connected to technique limitations of mass-spectrometer measurements. This matter strongly complicates a quantitative evaluation of the result.

One can affirm that the experimental data brought by A.Kladov are an evidence of admixture accumulation of foreign elements.

Experiments with radioactive isotopes  $^{137}\text{Cs}$ ,  $^{60}\text{Co}$ ,  $^{197}\text{Hg}$ ,  $^{188}\text{Pt}$ ,  $^{126}\text{Sn}$ ,  $^{40}\text{K}$  are also described in this paper. The author insists that his installation changes the quantity of radioactive nuclei, i.e. a transmutation of radioactive isotopes into stable isotopes occurs. Furthermore, the author notes a volume decrease of radioactive solution in the activator despite the guaranteed impermeability of the device. The average rate of solution reduction is 28 ml/h. Separately, the author establishes a fact of registration of some radiation and of correlation of its intensity with a change of activator operation mode. A substantial activity decrease of plutonium-beryllium neutron source after the operation of activator is specially stressed. The source was located at a distance of 2.4 m from the activator. The author assumes cavitation to be a main acting factor in the represented technological processes.

To conclude the section, we note that different authors in the above works, independently from each other and using various physical installations could observe the low energy element transmutation. Element composition of end products in these experiments has common features: foreign elements that were absent in the initial material appear, the content of light elements from Na to Zn substantially increases. No radioactive radiation was registered during the tests. The end product is not radioactive.

## **2 Check experiments on element transmutation at electric explosion**

### *2.1 Technique of experiments*

The subject of our investigation was barely an analysis of element and isotope composition of the substance that was in the working cells of the installation prior to and after electric explosion. Foil electric explosions were carried out by us together with the group of L.I.Urutskov at their installation [1]. Three techniques of analysis were used for that purpose: mass spectrometric analysis (MSA), x-ray fluorescence analysis (XFA), gamma- and neutron activation analysis (GAA and NAA).

The samples to be analyzed can be conditionally divided into two groups. The first group included the samples, which were obtained in our presence, under our supervision (Table 1a). Our distilled water was used in those experiments; the charging procedure of explosion cells, the explosion itself and water management into glass containers containing suspended products of foil electric explosion was visually controlled in our presence. The second group included assays obtained without our control (Table 1b). The conditions for the experiment – load material, liquid dielectric medium, where the electric explosion occurs, electric features of discharge- were chosen in a way that would guarantee the maximum output of foreign elements and it was based on a broad selection of experimental data on electric explosions carried out by the group of L.I.Urutskov.

Table 1.a The list of the investigated samples received under our control.

№ sample	load (foil)	medium	Number of samples
662	Ta	H <sub>2</sub> O	8
663	Ti №1	H <sub>2</sub> O	8
665	Ta + Fe-Ni + Ta	H <sub>2</sub> O <sub>2</sub> (1%)	8
666	Ta + Pb + Ta	H <sub>2</sub> O <sub>2</sub> (1%)	8

Table 1.b The list of the investigated samples received without our control.

№ sample	load (foil)	medium	Number of samples
668 - 8	Ta + Pb + Ta	H <sub>2</sub> O <sub>2</sub> (1%)	1
669 - 4,8	Ta + Pb + Ta	H <sub>2</sub> O <sub>2</sub> (3%)	2
670 - 8	Ta + Pb + Ta	H <sub>2</sub> O <sub>2</sub> (10%)	1
660, 661,664,671-7	Ti №2	glycerin	4
414	Ti №1	H <sub>2</sub> O	1
415	Ti №1	H <sub>2</sub> O <sub>2</sub> (1%)	1
453	Ni	H <sub>2</sub> O	1

We steamed the samples, obtained in this way with suspended products of foil electric explosion in water phase, in glass containers under drying lamps at a temperature ~60÷70 °C and then poured them into cassettes made from plexiglass and 20 µm thick mylar foil and then they were dried under the same conditions. The glycerin base assays were steamed on electric range at a temperature ~ 250 °C up to the moment when a visible liquid residue remained on the bottom of glass containers. That residue was poured into cassettes and was dried under drying lamps at a temperature ~60-70 °C. In both cases the temperature was controlled by a thermocouple. The dry samples were submitted for further analysis.

The results of analyses are summarized in tables and partly represented as bar charts. A following remark should be done for a better understanding of the material presented. From all techniques used, the volume activation technique by neutrons or gamma-quanta is the most sensitive one and free of inaccuracies if compared with XFA and MSA techniques. However, in order to determine the content of a particular element by activation technique, the sample should be irradiated and its activity should be measured during a time, which is the most suitable for this element. Therefore, the following strategy to analyze samples has been adopted. At the first stage, element sample analysis was carried out by means of x-ray fluorescence and mass spectrometer analysis. These measurements singled out elements which sample content differed from their content in initial materials. At the second stage, experiments on  $(\gamma,n)$ - or  $(n,\gamma)$ -activation of samples were run in order to confirm the results obtained by previous techniques. For this purpose the samples were irradiated and measured in conditions, which were the optimal ones for a particular element. Reference samples containing a known quantity of the element in question were irradiated simultaneously with samples. The measurements of gamma-radiation of activated samples and reference samples were carried out at two Ge(Li)-detectors. If need be, the activated samples were measured several times. This technique allowed to improve the content determination precision for elements in question in samples.

X-ray sample spectra of x-ray fluorescence analysis were obtained at the Si(Li)-spectrometer with a resolution 230 eV. The spectrometer enabled to find out elements starting from scandium. Electron shell excitation of the atoms in samples was performed by radioactive sources  $^{109}\text{Cd}$  and  $^{241}\text{Am}$ . Sensitivity level of the spectrometer equaled, for various elements and samples up to  $10^{-4}\%$ .

Laser mass spectrometer MS-3101 was used to fulfill mass spectrometric measurements. Ions were registered on photographic film. The density of film blackening was measured by automated spectrum measurer. Samples were prepared by the technique of pressure test of dry material on an aluminum substrate. Atom ionization of sample substance occurred in the laser radiation focus range that was used to scan the sample surface. The diameter of ionization zone was  $\sim 50\ \mu\text{m}$ . Elements to be determined ranged from lithium to uranium. Relative limit of element detection was equal up to  $10^{-5}$ .

The gamma- and neutron activation of samples was carried out at the electron accelerator with a maximum electron energy 25 MeV and a current 14-15  $\mu\text{A}$ . Depending on an element to be analyzed, the samples were located either in the gamma-quantum beam or in the thermal neutron field. Gamma-radiation of irradiated samples and reference samples were mea-



sured at two Ge(Li)-detectors with a volume  $30 \text{ cm}^3$ . The energy resolution of spectrometers was 4.5 keV. The sensitivity level of the technique for the elements under analysis amounted to  $10^{-6} \text{ g/g}$ .

The same Ge(Li)-detectors were used first to check the dry samples in order to detect in them the gamma-activity. The beta activity of samples was checked by means of the dosimeter DKS-B3 with a 42mm gas counter. It should be noted right away that no gamma- or beta activity was detected in any sample.

## 2.2 Measurement results and their discussion

Totally we have analyzed the results of 13 experiments. Furthermore, we have taken to analysis samples of current supply electrode and foils that were used as electric load. Composition of admixtures, contained in water and polyethylene, was also analyzed. Composition of admixtures in glycerin was taken from the technical passport. The quantity of samples and foil samples totaled 52. 60 XFA spectra, 47 mass spectra and 110 gamma spectra after GAA and NAA were obtained.

Due to a significant volume of the facts, we singled out the obtained measurement results and corresponding comments as Appendix. Measurement data are given in Tables 2-10 and partly are depicted in bar charts. The present section describes the results of sample analyses as aggregated data of all experiments.

As a result of electric explosion of tantalum foil in distilled water, mass spectrometry showed an increased content in assays of the following elements: Na, Al, K, Ca, Mn, Fe and Ni. The x-ray fluorescence analysis demonstrated the presence of nickel, molybdenum and lead. We remind you that the XFA allowed to detect elements starting from scandium. The same assays showed a substantial quantity of titanium that gets to the solution as we suppose as a result of substance separation from the central current supply electrode made of titanium. It is interesting to note that only in this experiment and in one of the experiments where tantalum and lead were used as a load, and a one percent hydrogen peroxide ( $\text{H}_2\text{O}_2$ ) as used as liquid dielectric medium (LDM), we found a substantial change in the isotopic-abundance ratio of titanium. It should be noted that our experiments did not show any rigid correlation between the appearance of foreign elements and the change of the isotopic-abundance ratio of titanium, as was observed in his experiments by L.I.Urutskov [1]. This is likely to be connected to the fact that the level of foreign elements in the majority of our experiments does not exceed 1-2 percent, while this level in the experiments by L.I.Urutskov averaged four percent. Thus, in the majority of our experi-

ments, isotopic shift is within the errors admissible for the MSA technique. However it should be stressed that in two out of three cases the level of foreign elements exceeded 10 percent (Table 2, Appendixes). As we link the appearance of titanium in these assays to the substance separation from the titanium current supply electrode, the change of isotopic composition of titanium evidences its participation in transmutation reactions.

In cases, when simultaneously tantalum and lead foils served as load, and hydrogen peroxide solution served as liquid dielectric medium, mass spectrometry also showed an increased content of admixture elements in assays and appearance of foreign elements such as: Na, Al, Si, P, K, Ca, Fe, Ni, Cu. The x-ray fluorescence analysis demonstrates an increased content of Mn, Ni in assays and, additionally, it detects the presence of antimony.

When tantalum and iron-nickel foils were simultaneously used as load, and one-percent hydrogen peroxide was used as medium, the mass spectroscopy analysis detected in the assays deviations in the content of elements Na, Si, K, Ca, Cu, Nb. The x-ray fluorescence analysis demonstrated the presence of antimony in assays.

When titanium foil was used as load, and water or one-percent hydrogen peroxide was used as medium, the MS-analysis detected in the assays deviations in the content of elements Na, Al, Si, K, Ca, Mn, Ni, Cu, Ag, Sn, Sb, Ba, Ta, Pb. The x-ray fluorescence analysis detected the presence of elements Mn, Ni, Cu, Zn, Y, Zr, Mo, In, Sn, Sb, Pb. A relative growth of admixture elements and a level of foreign elements comparable to the sensitivity level of experiment technique, where titanium foil underwent an electric explosion in one-percent hydrogen peroxide, is shown in demonstrational figure 4a. In the case, that glycerin ( $C_3H_8O_3$ ) was used as a medium, the x-ray fluorescence analysis showed a stable, from one assay to another, increase of such admixture elements as: Mn, Fe, Ni, Cu, Zn. In one experiment where the conditions of discharge flow were changed, no manganese was found, but instead of it, an increased content of lead was registered, Fig. 4b.

Fig. 4c represents the results of mass spectrometric analysis of an assay obtained through electric explosion of nickel foil in distilled water. The MSA analysis showed an increased content of admixture elements in the assay: Na, Si, K, Ca and appearance of new foreign elements: Zr, Nb, Ag, Sn, Sb, Ba, Ta. The appearance of Ag and Sb was noted in all types of analysis. Moreover, the x-ray fluorescence analysis showed a presence of Y, Zr and Pb in that assay.

The GAA and NAA confirmed the appearance of foreign elements in the assays such as: Na, Mn, Sb and displayed chlorine in the assays, i.e. an element that does not get registered by other types of analysis available.

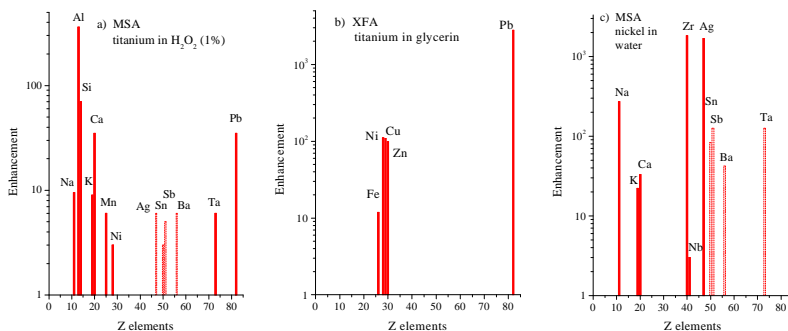


Fig. 4. Relative growth of admixture elements and foreign elements output in assays after electric explosion for the most explicit experiments. Analysis technique, load material, and dielectric medium are shown in Figures. Elements, which presence is sure, but the absolute value of admixture has an upper limit, are shown with a dotted line (see Appendix).

Here it is necessary to discuss all possible sources of bringing in of impurities that are present in the experiment, the influence of assay preparation techniques and sources of systematic errors of the analyses applied.

At electric explosion, a partial depressurization occurs, due to a powerful hydraulic shock, and this causes an emission of 10÷15% of substance in the surrounding space along the surface of current supply electrodes. That is why it is not appropriate to talk about absolute admixture content of foreign elements, and we quote here all data in relative concentrations.

Four types of sources of element admixtures are present in the experiments described, which can influence the end result: liquid dielectric medium – double-distilled water, glycerin, hydrogen peroxide, polyethylene walls of explosion cells, titanium rod of the central current supply electrode, material of foils to be exploded (load). Admixture percentage analysis in central electrode and disposable load foils was run simultaneously with electric explosion assay analysis. On one hand, it allowed to directly compare the element percentage, on the other hand, to reduce maximally an absolute value of systematic error. Therefore, these data are included in the same Tables 4-9, as the assay data.

Admixture data in liquid dielectric media and polyethylene are given in the Appendix. The volume of liquids in explosion cells amounted to 35-50  $cm^3$ . Hence it is easy to evaluate that the assay admixture contribution from the liquid dielectric media, taking into account their volumes, is substantially less than the admixture value in foils and central titanium electrode. The

question of polyethylene seems to be more complicated. Electric explosion in liquid medium is accompanied by a blast wave where the pressure on cell walls may achieve values that are capable to destroy the surface polyethylene layer. It is obvious that together with polyethylene, the admixtures dissolved in polyethylene get into the liquid. Mass spectrometric analysis showed no carbon in the assays under investigation. However, in private communications, L.I.Urutskov reports a presence of carbon in the amount up to 1% in some experiments and he believes that its appearance is completely related to the destruction of polyethylene wall of explosion cell. Therefore, we normalized the presence of other admixture elements emitted from polyethylene vs. one-percent carbon admixture.

The experiments with electric explosions of foils made from Ta, Fe, Pb, Ni or their combinations showed the presence of titanium in assays, the content of titanium runs up to dozens percent. We associate, as shown above, the appearance of titanium in assays with a destruction of central current supply electrode during the flow of current pulse. Other element impurity contribution from the electrode was evaluated by the same technique as that for polyethylene. Hypothetical mechanisms of selective extraction of one or another element from the electrode or from polyethylene at electric explosion were not taken into consideration.

The admixture analysis according to the above technique showed that the appearance of some chemical elements in assays is in no way connected with the destruction of titanium electrode or, even more so, of polyethylene.

The data given in Tables 2-10 demonstrate that the element percentage in one and the same assay differs significantly depending on an analysis technique. Such substantial differences are caused by systematic measurements errors having different nature the x-ray fluorescence and mass spectrometric analyses.

The source of errors at x-ray fluorescence analysis is that the gamma-quanta of various energy pass the volume thickness in different ways. Softer gamma-quanta are adsorbed by the assay substance. Therefore, depending on assay composition (its main element) and thickness, the relative element content varies. Furthermore, an assay is predominantly composed of the element, which was a load at electric explosion. This makes the x-ray lines of some elements to be superimposed on the "powerful" peaks of main element. In some cases this causes an increased error in quantity determination of elements analyzed in an assay, in other cases, this makes it impossible to do such analysis for some elements.

The systematic mass spectrometry error is determined by the way of ion beam production and photographic film analysis technique. At assay ioniza-

tion, the laser beam burns out at sample surfaces the spots of  $\sim 50 \mu\text{m}$ . Characteristic local formations of  $50 \mu\text{m}$  and more that appear at electric explosion make the assay content vary greatly depending on what place of sample surface the laser beam has got to.

The ion quantity of one or another element is determined by blackening density of the photographic film that is located in the focal plane of magnetic analyzer. The relative element content in an assay is determined by relative blackening of the photographic film for this element and for the main assay element (maximal blackening). The dynamic range of microdensimeter was smaller than quantity ratio of admixtures and main element. Therefore, a cascade calibration of the instrument had been carried out in the process of measurements, what inevitably induces an additional spread of the data. A thorough film analysis by means of microphotometer showed that, during film preparation, defects are formed at the places of blackening which decrease the blackening density. This fact does also contribute its systematic error to a final result. For above reasons, the results obtained by means of XFA and MSA analyses are, for low admixture levels in samples, rather of qualitative than of quantitative nature. As already noted, the structure of a dry assay contains explicit heterogenous inclusions, we did not homogenize them to avoid an uncontrolled bringing in of foreign elements. For this reason, both XFA and MSA techniques yield a local element concentration what results in a substantial difference of admixture composition within one assay and in the fact that composition data differ from the average values of element concentration in an assay.

The volume activation analysis has practically no sources of systematic errors. The disadvantage of the technique is that not all stable isotopes can be activated in order to analyze their content in samples.

To conclude the check experiments carried out, most substantial experiment features should be noted. Our investigations confirmed, in general terms, the results of experiments on element transmutation at electric explosion of foils in dielectric medium obtained by the group of L.I.Urutskoev. As a result of electric explosions, the assays show foreign elements and a substantially increased admixture content of some elements, which are present in initial foils and titanium electrode rod.

We have recorded the appearance of foreign elements in assays and an increased content of admixture elements. These elements include: Na, Al, Si, P, K, Ca, Cl, Mn, Fe, Ni, Cu, Zn, Y, Zr, Mo, Ag, In, Sn, Sb, Ba, Ta, Pb. Decreased element admixtures that are present in foils are observed in some assays. Absolute quantity of new element atoms, which appeared after electric explosions, are in the range  $10^{15} \div 10^{18}$ .

A change in titanium isotopic-abundance ratio is seen in some assays.

The composition and quantity of admixtures after electric explosion depends both on load composition and liquid dielectric medium.

Gamma and beta activity were not found in any assay.

### 3 Analysis of low energy element transmutation

In previous sections, devoted to experimental check of element composition change as a result of transmutation, a reliable increase of content of one group of elements and the appearance of other, foreign elements has been noted. Furthermore, electric explosion experiments revealed a violation of isotope composition of Ti. It should be noted straight away that such element transformations cannot be explained from the point of view of modern physical notions both because of impossibility for nuclei to overcome the Coulomb barrier and because of impossibility to construct elements observed while the number of protons is conserved. To eliminate the last contradiction, we have to include electrons into input or output channels, thus supposing a possibility of weak reactions with  $l$  electrons, i.e. to account for improbable reactions for charge transformations:



where  ${}^n_z A$  is a nuclide with a charge  $Z$  and an atomic number  $n$ .

Another probability prohibition of transmutation processes is kinetics. It appears because the nuclei cannot collide during electric explosion as often as to provide for the quantity of new elements (up to 1%). Below we discuss numerical scales of these three prohibitions. Since all these prohibitions for transmutation processes the form of extremely low probability of the process, we shall use, for simplicity purposes, the term: probability prohibitions. However, it is completely not evident that conservation laws linked with space and time property are observed. Unfortunately, we are lacking experimental data to check the angular momentum conservation law. However, it is possible to check the energy conservation law. Our problem definition reduces such a check to the task to see exothermic nuclear reactions leading to foreign elements, which can be observed experimentally. Energy release in these reactions occurs owing to a difference in the sums of atomic nuclei masses in the input and output reaction channels. At the same time, it is meant that the energy balance should account not for the nucleus mass only, but for the  $l$  mass of electrons. Moreover, to provide for the purity of the check, below we took into account the electron binding energy in atoms, too.

Reference book [7] was used to analyze possible reactions. The Table included stable and radioactive isotopes with half-lives more than 10 years, or, in case of the absence of stable isotopes, an isotope with maximal possible lifetime was taken. The binding energy of electrons of an atom was taken into account according to formula  $E_A = 16.Z^{7/3}$  within the Thomas-Fermi model [8].

### 3.1 Reactions of load elements Ti and Ni

Ti and Ni reactions have been considered for the analysis. Because of limited technical possibilities, we accounted for not more than three output nuclides. i.e., all reactions were considered:

$$L_z^n A = {}_{z_1}^{n_1} A_1 + {}_{z_2}^{n_2} A_2 + l e^- + l \tilde{\nu}_e + Q; \quad L_z^n A = {}_{z_1}^{n_1} A_1 + {}_{z_2}^{n_2} A_2 + {}_{z_3}^{n_3} A_3 + l e^- + l \tilde{\nu}_e + Q;$$

$$L_z^n A + l e^- = {}_{z_1}^{n_1} A_1 + {}_{z_2}^{n_2} A_2 + l \nu + Q; \quad L_z^n A + l e^- = {}_{z_1}^{n_1} A_1 + {}_{z_2}^{n_2} A_2 + {}_{z_3}^{n_3} A_3 + l \nu + Q,$$

under additional conditions: nucleon number conservation  $n_1 + n_2 = Ln$  and  $n_1 + n_2 + n_3 = Ln$ ; total charge conservation  $z_1 + z_2 = Lz \pm l$  and  $z_1 + z_2 + z_3 = Lz \pm l$  and positive balance of energy  $Q \geq 0$ . A preliminary conclusion about the possibilities of such reactions follows from consideration of binding energy per nucleon in the nuclei of initial substance, Fig.5. Thus, the main isotope  ${}^{58}\text{Ni}$  (~68%), which has a minimal, from all nickel isotopes, binding energy

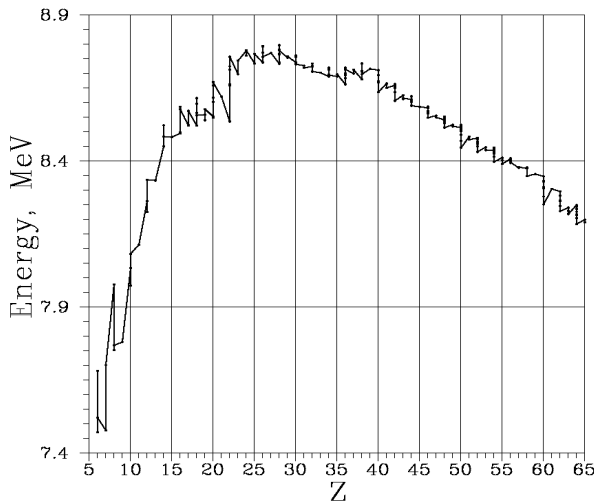
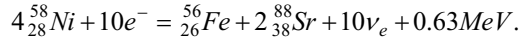
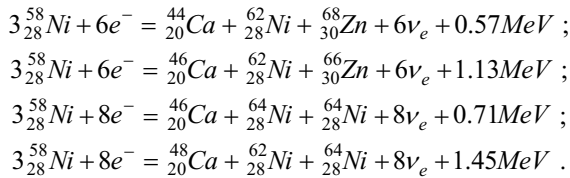


Fig. 5. Binding energy per nucleon in atomic nuclei.

per nucleon 8.732 MeV, can generate, in reactions with three output nuclides, a maximal heavy element with  $Z=38$  (strontium). The calculations show that such fusion is possible in reactions with ten weak interactions in the reaction:

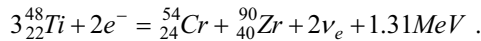


At the same time, the most light product of reactions – calcium is obtained in four reactions:



Reactions with proton number conservation do not exist. The maximal quantity of elements at the output falls on other isotopes of nickel and iron.

Titanium has a broader spectrum of output elements. Thus, the main isotope  $^{48}\text{Ti}$  (~74%), with binding energy per nucleon 8.723 MeV, can be yielded by zirconium, the maximal heavy element, in many reactions. We will quote a single reaction, with two output fragments:



Silicon is the most light element obtained in reactions  $^{48}\text{Ti}$  between each other. There are many reactions and we won't quote them.

The most light titanium isotope  $^{46}\text{Ti}$  with a relative content ~8% has a minimal binding energy per nucleon 8.534 MeV and can generate cadmium in reactions with five isotopes  $^{46}\text{Ti}$  and six electrons.

### 3.2 Reactions with medium elements

We start from a trivial statement that any elements of periodic table can be obtained from protons, taking into account weak interaction. Not giving here calculations, we indicate, that elements from  $^{17}\text{O}$  to  $^{234}\text{U}$  can be built from the group OH. Water extends this row into the sphere of super-heavy elements (interpolation of curves yields a crossing area at  $Z \approx 110$ ).

Reactions of medium elements with load elements are of much greater interest. As an example, we consider reactions  $^{58}\text{Ni}$  and  $^{48}\text{Ti}$  with L-elements  $^{16}\text{O}$ . Energy outputs in the reactions  $^{58}\text{Ni}$  with L-elements  $^{16}\text{O}$  are given in



Fig.6B. The element number ( $Z$ ), which is constructed of such combinations, is plotted along the axis of abscissa. A reaction with pure oxygen is given for comparison. Since there are many, as a rule, output channels with an output of a given element, we shortly indicate the construction technique of these curves. The following scheme has been chosen for reactions with pure oxygen. Element with number  $Z$  was chosen from reactions with two output elements and a minimal value  $L$ :

$$L {}_8^{16}\text{O} + le^- = {}_{z_1}^{n_1}\text{A}_1 + {}_{L8-z_1-l}^{L16-n_1}\text{A}_2 + lv_e + Q, \quad z_1 \leq 8.$$

In cases, when a given element does not exist in the indicated reaction, the element was present in reactions with three output elements. In Figure, a dotted line corresponds to such elements.  ${}^{180}\text{W}$  with binding energy per nucleon 8.026 MeV at  $L=12$  is the heaviest element that can be obtained from this oxygen isotope with binding energy per nucleon 7.976 MeV. For oxygen reactions with nickel, an output channel with a minimal value of  $L$  and a maximal value of energy release  $Q$  was chosen:

$$L {}_8^{16}\text{O} + {}_{28}^{58}\text{Ni} + le^- = {}_{z_1}^{n_1}\text{A}_1 + {}_{28+L8-z_1-l}^{58+L16-n_1}\text{A}_2 + lv_e + Q.$$

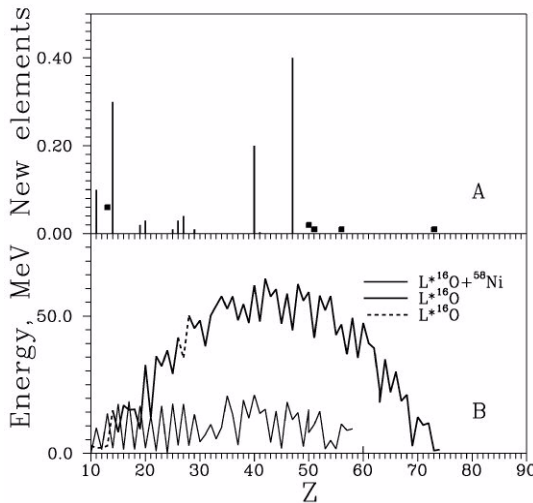
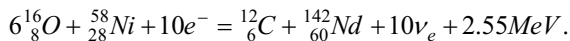


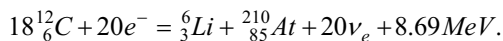
Fig. 6. New elements admixture in the assay 453 ( $\text{Ni} + \text{H}_2\text{O}$ ), percentage wise (A) and energy release in reactions  ${}^{58}\text{Ni}$  and  ${}^{16}\text{O}$  as a function of charge of an element to be synthesized (B).

At that, all output channels were two-element channels. Let us note that high “brockeness” of the energy release curve in these reactions is largely determined by the alternation of the quantity L, than by the difference of binding energy of output elements. Neodymium, which requires 6 atoms of oxygen, is the heaviest element, obtained in these reactions:



The most bright data of the assay 453 are given in Fig.6A for comparison. At that, elements, which presence is certain, are marked with filled squares, but an absolute value of the admixture plays the role of upper limit (see Appendix). It is seen that in reactions between  $^{58}Ni$  and  $^{16}O$  we can obtain more and more new elements, with the exception of tantalum. A possible configuration of initial sample, containing both nickel and oxygen, can be oxide film. In this case, nickel oxide (II) has a lattice, which is similar to NaCl, i.e. one nickel ion has 6 closest neighbors: oxygen atoms. The appearance of tantalum can be explained by reactions between elements of the medium only. In particular, it can be built from oxygen. Reactions of oxygen with titanium generate elements from hydrogen to  $^{148}_{62}Sm$ . In order not to repeat the figure similar to Fig. 6, we give Fig.7, where an experimental element distribution and two distributions calculated not by energy release, but by the combination quantity of output elements in reactions between titanium-48 and titanium with oxygen are compared. It is self-evident that distributions boundaries only can be compared.

We don't quote here figures with carbon participation. We just mention that, in reactions with two output elements, we can obtain from carbon all elements, down to astatine:



Reasoning from assumption that a probability of production of new elements decreases as the quantity of nuclei in input and output channels decreases, one can conclude that the following group of elements - Na, Al, Si, K, Ca, Cl, Mn, Fe, Ni, Cu, Zn – is generated by the elements of load and load+medium. Another group of elements - Mo, Ag, In, Sn, Sb – is generated in combination of elements of load and medium. The heavier elements - Pb, Ta – can be generated by medium elements only. In this case, the medium should contain either carbon or the group (OH). Let us remind you that these calculations were for a limited quantity of output nuclides: their number should not exceed three.

Thus, an analysis carried out to check the energy conservation law for new elements obtained in experiments with electric explosion of load shows that all admixture elements can be obtained from initial nuclei at a positive energy output. However, the experiment on changing the element composition of pure zirconium that has been discussed in the first part of the paper, should be analyzed additionally, because the zirconium melting occurred in a vacuum. I.e., natural isotope composition of Zr is the only initial element for the production of all elements shown in Fig.8, down to Lu, which binding energy per nucleon is substantially less, than in all zirconium isotopes.

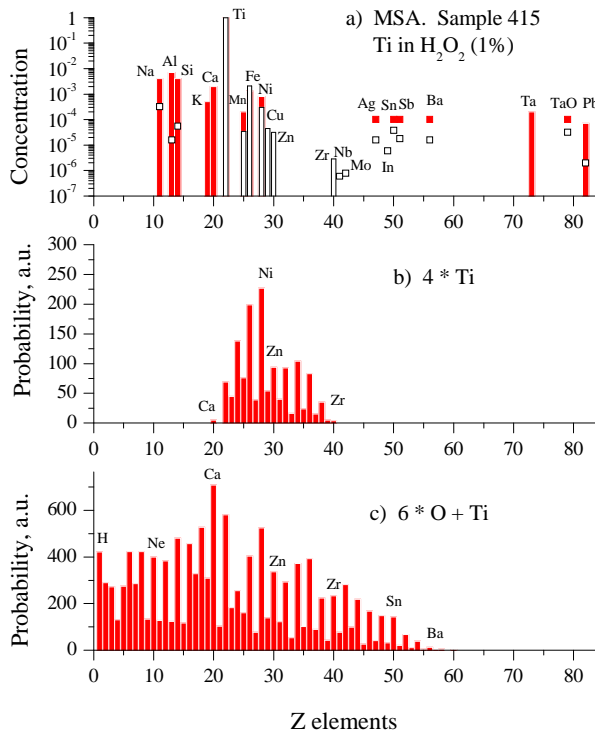


Fig. 7. Comparison of experimental element composition of sample 415 after electric explosion with calculated relative probabilities of creation of elements: a) sample 415, load – Ti, medium - H<sub>2</sub>O<sub>2</sub> (1%); b) calculation made for four nuclei of <sup>48</sup>Ti in the input reaction channel; c) calculation made for six nuclei of <sup>16</sup>O and <sup>48</sup>Ti in the input reaction channel.

### 3.3 Reactions with Zr

A spectrum of elements obtained after zirconium melting is shown in Fig.8. We obtained this spectrum by transformation of mass spectra Fig.2. Reactions of two main isotopes  $^{90}_{40}\text{Zr}$  (~51%) proceed to decay side and yield elements from silicon to strontium. The reaction spectrum of two isotopes  $^{96}_{40}\text{Zr}$  (~2.8%) is much more reach and includes deuterium, and then spreads continuously from carbon to palladium. We can obtain from deuterium heavier and heavier elements. However, to remove all doubts about light gas participation in further reactions, we note that carbon also yields all elements shown in Fig.8. There are six reactions with carbon output from two atoms  $^{96}_{40}\text{Zr}$ , which we do not quote here because of their obviousness. Reactions that results in heavy elements are supposed to have two mechanisms. They are either a successive production of carbon and other light elements, which have a binding energy per nucleon that is close that of carbon, and their further participation in the formation of new elements or a participation of a greater quantity of zirconium atoms in the reaction simul-

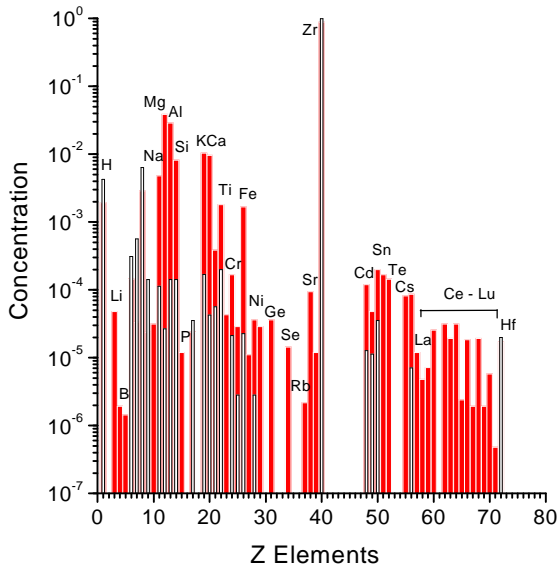
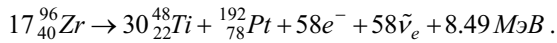
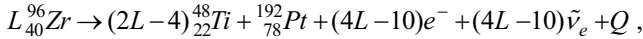


Fig. 8. Element composition of zirconium ingot. Filled bar graphs stand for after electric explosion, unfilled bar graphs stand for before electric explosion.

taneously. The latter does not seem obvious, and we quote here a reaction that generates platinum, an element that is heavier than Lu (Fig.8):



Generally speaking, the general formula of this reaction



at  $L > 16$  has a positive energy output  $Q$ . Despite the appearance of platinum, the charge balance of this reaction indicates a predominance of light elements. Let us tell for information that at  $L=20$  the energy output of the reaction is 36.9 MeV.

Performed calculations show that the production of foreign elements in a low energy transmutation reaction does not contradict to energy conservation law. Moreover, some reactions have such a significant energy output that they could be a base for energy generating installations. It is self-evident, at a much greater portion of nuclei to be transformed and at understanding of physical reasons causing the low energy transmutation.

### 3.4 Discussion of theoretical prohibitions of low energy transmutation

As we have already mentioned above, transmutations at low energies can not be explained within modern physical conceptions. To be more precise, the portion of changing nuclei must be so tiny that it cannot be detected. We see three theoretical prohibitions for transmutation phenomenon: the impossibility to pass the Coulomb barrier, small, to the limit, probabilities of weak processes and small probabilities of multi-particle collisions, even if the Coulomb barrier is absent. In order to rely on numerical values of these small probabilities, we quote their estimated values.

The Coulomb barrier can be accounted for from the evaluation of nuclear reaction cross-section at low energies:

$$\sigma_r = \tilde{\sigma} |\Psi_C(0)|^2,$$

where  $|\Psi_C(r)|^2$  is a squared Coulomb wave function of the relative motion of nuclei determining the probability of passing the Coulomb barrier,  $\tilde{\sigma}$  is nuclear reaction cross-section at the “switched-off” Coulomb barrier. Below we shall use its geographical scale equal to one barn ( $10^{-24} \text{ cm}^2$ ). Then, a probability of nuclear reaction per time unit, related to one atom, will be determined by a simple formula:

$$W_n \approx nv\sigma_r ,$$

where  $n$  is atomic density of matter, and  $v$  is a rate of nuclear collisions at a certain energy  $E$ . Taking into account the expression for the value of Coulomb wave function in zero at small energies  $|\Psi_C(0)|^2 = e^{-2\pi/ka} 2\pi/ka$  (see, for instance, [8]), where  $k$  is a wave number, corresponding to nuclear collisions energy, and  $a$  is Bohr radius for Coulomb parameters of colliding nuclei, we can obtain an evaluation of probability of titanium nuclei reactions per one second:

$$W_n \approx 3.7 \cdot 10^{10} e^{-106567/\sqrt{E}} .$$

Here, the energy  $E$  should be substituted in eV units. I.e. a probability of nuclear reaction at a typical energy of one electron-volt is determined by a decimal degree  $\sim 46000$ . Thus, no nuclear reaction with titanium will take place during the lifetime of the Universe at these energies. In order to avoid hypothesis on cumulative processes, let us note that even if the nuclei had an energy of the voltage applied to electrodes of 4 keV, then in this case a probability would be determined by a decimal order  $\sim 720$  and would be, as before, incredible in the Universe. One can say that the Coulomb barrier forbids practically absolutely reactions observed in the experiment.

Let us now discuss the magnitude of velocities of weak transitions. In order to avoid the complexity of model presentations, we shall proceed from dimensions considerations and experimental values of lifetimes of radioactive nuclei that capture an electron. Such nuclei can live for years. However, there exist such radioactive nuclei, which lifetime is determined by minutes. For example, the nucleus of tungsten  ${}_{74}^{173}W$  captures an electron in the course of 16.5 minutes. For evaluation, let us take an overstated velocity of electron capture by a nucleus – one transition per second. Dimensional considerations allow to write down an expression for the velocities of weak transitions in the form:

$$W_w \sim \frac{\Delta E}{\hbar} \alpha ,$$

where  $\Delta E$  is energy released at weak interaction, and quantity  $\alpha$  is dimensionless constant. Double and triple beta transitions will be determined just by the degree, i.e.  $\alpha^2$  and  $\alpha^3$ , correspondingly. Let us evaluate this quantity. For  $W_w = 1/c\epsilon\kappa$  and  $\Delta E = 1M\text{eB}$ , we obtain  $\alpha \sim 10^{-21}$ . The typical time of duration of current flow at electric explosion is 10  $\mu\text{s}$ . It means that even

at such overstated velocities of weak transitions, we would not obtain more than thousandth percent of transformed nuclei. If we take into account that, as a rule, two weak transitions per nucleus occur in given formulas, then a velocity of double weak transitions will be  $\sim 10^{-21}$  /sec, a quantity, which determines one double transition per hundred moles of substance during experiment time.

The last probability prohibition is kinematics, it is determined by dimensions of nuclei, which are too small even for three particle collisions. Really, a probability of a particle pair to get into the volume  $V$ , occupied by a three particle, is  $V^2/V_{Tot}^2$ , where  $V_{Tot}$  is a full volume occupied by  $N$  particles. The quantity of double combinations from  $N$  particles will be equal to  $N^2/2$ . Thus, volume  $V$  always contains  $V^2 n^2/2$  three-piece sets of particles. For velocity evaluation of probability of three-particle collision formation, the last quantity should be divided over the time of typical stay in this volume:

$$W_K \sim V^2 n^2 / 2\tau .$$

We have two length parameters:  $R$ , determining the volume  $V$ , and a mean distance between particles  $n^{-1/3}$ , that is why the typical time  $\tau$  is determined by an interval from  $n^{-1/3}/v$  to  $R/v$ . Let us take an overstated velocity of formation of three-particle collision formation according to the shortest time  $\tau = R/v$ . Evaluating the size of nucleus  $R$  as  $10^{-12}$  cm, the motion energy of titanium nuclei as 1 eV and taking the density of metallic titanium, we receive  $W_K \sim 10^{-14}$  /sec. Thus, a probability of three-particle collisions, related to one atom, will have a scale  $\sim 10^{-19}$  during the time of experiment, while the observed value is  $\sim 0.01$ . I.e. three-particle (and more) collisions are clearly not sufficient for the production of the observed quantity of elements.

The considered probability prohibitions for nuclear transmutation at the energy scale of 1 eV cannot be overpassed within traditional physical conceptions. It especially concerns the kinetic prohibition, which cannot be overpassed even by introduction of hypothetic particles, which are intermediaries to bring the nuclei closer to each other. However, experimental data show the existence of transmutation. As kinetic prohibition is based on dimensions of a nucleus, let us evaluate, what should be the size of interaction area  $R$ , sufficient to obtain one percent of transmuted nuclei during 10  $\mu$ s. Simple calculations yield a surprising value  $\sim 10^{-9}$  cm. If we take maximal

time  $\tau = n^{-1/3} / \nu$ , we obtain  $R \sim 10^{-8} \text{ cm}$ . I.e. both evaluations give a size close to the size of an atom. Let us note that if a number of particles participating in the reaction increases, then the quickly attainable limit  $R \sim n^{-1/3}$  does not depend on reaction velocities chosen or on typical collision times. Let us note that, at such dimensions of interaction area, not only removed are prohibitions imposed by the Coulomb barrier, the Coulomb barrier itself just disappears, but weak interaction is substantially accelerates. This takes place because the quantity  $\alpha$  contains a multiplier equal to volume ratio of a nucleus and an atom. If we substitute the quantity  $\alpha R^3 / 10^{-36}$  in the expression for double beta-process instead of  $\alpha$  and set time of  $10 \mu\text{s}$  and probability of 0.01, we can define the quantity  $R$ . It also proves to be equal to the size of an atom  $R \sim 10^{-8} \text{ cm}$ . Therefore, we can overpass all above prohibitions for nuclei, which size is equal to that of an atom. We cannot indicate mechanisms causing such big dimensions of atomic nuclei in conditions of an experiment. We just state the only, to our mind, possibility of transmutation. As a hypothesis, we can express an opinion on the change of fundamental physical constants under conditions of a physical experiment on element transmutation.

### Conclusion.

If you compare electric explosion experiments with zirconium melting and ultrasonic activation experiments (USA), attention should be drawn to the time difference of the low energy transmutation process in these tests. If, in the first case, the process takes tens microseconds, in other cases it takes tens minutes and even some days. Though we know neither what time is necessary for the transmutation process to take place, nor what time the conditions for this reaction to be initiated are available in the medium, it is plausible to assume that transmutation reaction density per medium unit is much greater at zirconium melting and ultrasonic activation than at electric explosion. Due to the above, we can assume that transmutation reaction at electric explosion proceeds, to a substantial degree, under participation of initial material only, while secondary elements, representing products of previous transmutations, can be involved in the reaction at zirconium melting and ultrasonic activation. This can have a radical impact on the spectrum of final products in the low energy element transmutation reaction. Most probably, this explains an irregularity of appearance of elements with  $Z > 30$  at electric explosion (Fig.4, 9-12), and an appearance of a broad spectrum of chemical elements (Fig.8) at zirconium electron beam melting and ultrasonic activation (Fig.3d).



The above experimental data on transmutation processes of chemical elements, despite all their fragmentariness, have a regularity common for various experiments. Moreover, a simple calculation of energy balance reveals possible participants of nuclear reactions. In particular, three and more atoms should be attracted into the input channel to explain all elements, which are observed. This necessarily requires to extend the reaction spheres up to atomic and greater dimensions. The nature of appearance of such conditions is unknown. Let us note that the correctness of the balance that has been considered when the lepton number is conserved can be checked by means of registration of neutrino (antineutrino) burst.

The authors wish to express their appreciation to L.I.Urutskov, for granting a possibility to run check experiments, to V.M.Dubovik for initiating discussions, and V.V.Pavlenko for informational support.

### Appendix

In view of extraordinary results of the present paper, we have considered it necessary to prepare comments on each check experiment, represented in Tables, and to represent, for obviousness, the content of some Tables as bar charts.

Data on mass spectrometric measurements are given in Tables 2–4, data on x-ray fluorescence analysis are demonstrated in Tables 5–8, and data on activation analysis are shown in Table 9. Data on sample 453 are brought together in Table 10. Admixture compositions, contained in water, glycerin and polyethylene, are given in Tables 11–13. Elements that appeared after electric explosion, but not registered in initial materials (foils, titanium electrode), as well as elements, which content in the assays increased, are bold typed in Tables. As this takes place, a statistical requirement on exceeding two standard errors is met. Marked with circles are elements, which were not registered in assays, but had been registered in initial materials. Elements, which content in assays decreased, are underlined. A symbol less or equal ( $\leq$ ) in Tables indicates, in cases of x-ray fluorescence analysis, as well as in those of gamma and neutron activation analysis, a technique sensitivity limit for a given element.

In case of mass spectrometric analysis the symbol less ( $<$ ) means that this element with all its isotopes was registered at a given level of sensitivity, but the statistical requirement on exceeding two standard errors is not met for an isotope with the lowest percentage. At that, the main element is determined reliably. Due to this, we consider the appearance of such elements in experiment as reliable and mark them on bar charts with separate squares.

Many mass spectra indicate the availability of gold in the assays. However, neutron activation analysis with a good sensitivity level ( $\leq 2 \cdot 8 \cdot 10^{-6}$ ) has not revealed this element in any assays. Our attention is drawn to the fact that the appearance of mass 197 in spectra fairly well coincides with the presence of tantalum in assays. That is why we consider tantalum oxide to be responsible for the appearance of mass 197 in spectra.

In the experiment No.662, tantalum was used as a load, and water served as medium. The results of MS-analysis of samples 662-3, 662-7 (Fig.9c) are given in Table 2b. Further, in all figures, filled bar graphs stand for the state after electric explosion (effect), unfilled bar graph stand for the state before electric explosion (background). Filled and unfilled squares show the level of sensitivity for effect and background, correspondingly. The assay composition should be compared with composition of Ta, which is represented in Table 4 and 8. It is seen that elements Na, Al, K, Ca, Ni have appeared. The content of Na is especially great in these assays: 14% and 6,8%. It can be seen that the assay also contains Ti. Its presence is likely to have a trivial explanation. A substantial energy release at contacts of foil and central electrode can be released at electric explosion, owing to this a matter from titanium electrode can get into solution (arcing, braking up of a substance). In this case, the content of central electrode substance in an assay can amount to dozens of percent. Naturally, all admixtures present in titanium can get into liquid dielectric medium. It should be noted here that though Fe and Mn are present in tantalum foil and in titanium electrode (Tables 8 and 9), their concentration, however, has increased substantially. It is especially seen for Mn. It cannot be explained by trivial reasons. As we shall see in what follows, this is a regular effect. These assays were also investigated by means of XFA (Table 8). Ni, as well as Mo and Pb are revealed in these assays by XFA, though in smaller quantities. Titanium isotope composition in the assay is given in Table 2a. It can be seen that titanium isotope ratio changed and became different from the natural isotope ratio:  $^{46}\text{Ti} : ^{47}\text{Ti} : ^{48}\text{Ti} : ^{49}\text{Ti} : ^{50}\text{Ti} = 8.0 : 7.3 : 73.8 : 5.5 : 5.4$ . [9].

In the experiment No.663, titanium was used as a load, and water served as medium. Data on the assays 663-6 and 663-8 show an increased content of Na, Si, Ag, Sn, Sb, Ba, Ta, appearance of K, Ca, and a decreased content of Ni (Table 2b). The content of Ni in initial titanium foil formed 0.03%, in the assay 663-6 – 0.01%, and no nickel was found in the assay 663-8. The XFA (Table 5) and MS-analysis (Table 2b) show a picture, which is somewhat different. The appearance of Ni in assays and variations of its quantity can be explained by the ingress of titanium electrode in the assay. This cannot be said about Mn, which presence in the assay does substantially exceeds

the content of Mn in foil and titanium electrode. Zirconium and niobium (Table 5) are found in foil, but not in the assays. The XFA (Table 5) confirmed the appearance of Sn, Sb in assays and showed a presence of other foreign elements, such as In, Pb. The appearance of Sb and content increase of Na, Mn is confirmed by activation analysis (Table 9). The gamma activation analysis showed a presence of chlorine in the assays.

A complicated electrode, with iron foil placed between tantalum foils, was used as load in the experiment No. 665. One-percent hydrogen peroxide water solution ( $H_2O_2$ ) served as medium. The data on this assay are represented in Tables 2a and 7. An MS-analysis of iron foil was not carried out and data on its composition are taken from the XFA. Deviations in the content of such elements as Cu, Nb were found in the assays by MSA technique. The x-ray fluorescence analysis showed a presence of antimony in assays. Moreover, the assays after electric explosion revealed a substantial change in the ratio of nickel, iron and manganese (Tab.7).

A complicated electrode, with lead foil placed between tantalum foils, was used as load in the experiment No.666. One-percent hydrogen peroxide water solution ( $H_2O_2$ ) served as medium. The results are given in Tables 2a (Fig.10c), 8 (Fig.11a) and 9. Mass spectrometric analysis showed an increased content of Na, Si, K, Ca, Fe, Ni, Cu in the assays, and phosphorus was found in the assay No.666-3. Here, a substantial shift in the isotope ratio for  $^{48}Ti$  up to  $(65\pm3)\%$  should be mentioned. It should be stressed that Ti could appear in the assay as a result of the ingress of titanium electrode into substance solution. The XFA confirmed an increased content of Ni and revealed an increase of Mn, Sb in the assay (Table 8). Activation analysis showed a presence of chlorine and an increase of Na, Mn, Sb in the assay No.666-1 (Table 9).

Nickel was used as load in experiment No.453 and water served as medium. The data on this experiment are shown in Tables 3b (Fig.9a) and 10 (Fig.11b). The MS-analysis showed an increased content of admixture elements in the assay: Na, Si, K, Ca and appearance of new – foreign elements: Zr, Nb and Ag. Moreover, the MS-analysis showed a presence of Sn, Sb, Ba and Ta in this assay; the presence of these elements in the assay exceeds, by two orders of magnitude, their presence in foil and central electrode samples. The appearance of Ag and Sb was noted in all kinds of analysis (Table 10). Furthermore, the XFA analysis showed the presence of Y, Zr and Pb in the assay.

Titanium was used as load in the experiment No. 415, and one-percent hydrogen peroxide water solution, which was previously saturated with hydrogen and helium, served as medium. The data are collected in Tables 3b

(Fig.9b) and 9. The MS-analysis showed an increased content of admixture elements Al, Si, K, Ca, Mn, Ni and appearance of foreign elements Ta and Pb in the assay. We have to note that Ta and Pb are absent in the titanium foil and electrode. Furthermore, the MS-analysis showed a presence of Ag, Sn, Sb, Ba in this assay; the presence of these elements exceeds, by three-seven times their presence in foil and central electrode samples. The XFA-analysis (Table 5) confirmed the appearance of Sn, Sb, Pb and found another foreign element – yttrium. The elements Cu, Zn, Zr are present in titanium electrode and foil. However, the assay showed an increased content of these element (Table 5), what can be hardly explained by an ingress of material of foil and electrode in water medium at electric explosion. The explosion of Na, Mn and Sb is confirmed by activation analysis (Table 9). Chlorine was found in the assay.

Titanium was used as load in experiment No.414, and water served as medium. The results of the XFA are given in Table 5 (Fig.11c), and the results on activation are given in Table 9. We can see from these data that both techniques yield a substantial increase of Mn content in the assay if compared with its presence in titanium foil and titanium electrode. An increase of Na, Cu, Zn is found in this assay, and also foreign elements such as Mo, Pb (Table 5) and Cl and Sb (Table 9) are detected. The x-ray fluorescence analysis in the element range In – Ba was not carried out.

Titanium was used as load in experiments No. 660, 661, 664, 671-7, and glycerin ( $C_3H_8O_3$ ) served as medium. Titanium foil No.2 with other output data, different from those of titanium foil No.1 from previous experiments was used in these experiments. The data on the experiments were gained by the XFA analysis only (see Table 6 and Fig.12a-d). Though such elements as Mn, Fe, Ni, Cu, Zn are present in titanium foil and titanium electrode, their relative content after electric explosion has practically increased by two orders of magnitude. All these experiments were carried out under the same conditions, with the exception of current pulse amplitudes supplied to loads. The maximal current quantity was realized in the experiment 660. Let us note that Pb appears and Mn disappears in this experiment (see Fig.12a).

In the experiments No. 668, 669 and 670, a composed electrode with lead foil between tantalum foils was used as a load. Hydrogen peroxide aqueous solution with concentrations 1%, 3% and 10% correspondingly was used as medium. The MSA data are given in Table 3b (Fig.10), and data gained by means of XFA and activation analysis – in Tables 8 and 9. These tests show that experiments provide for a good results repetition. Mass spectrometric analysis showed an increased content of Na, Al, Si, K, Ca, Fe, Ni, Cu in the assays. Both XFA (Table 8) and NAA show a considerable increase of Mn

in these assays. Besides that, foreign elements Cl (Table 9) and Sb (Tables 8, 9) appear in these assays. The admixture increase of Na and appearance of Sb is confirmed by activation analysis.

Table 2a. Isotope composition of the titan present in samples, MSA, mass. %.

$$^{46}\text{Ti}: ^{47}\text{Ti}: ^{48}\text{Ti}: ^{49}\text{Ti}: ^{50}\text{Ti} = 8.0: 7.3: 73.8: 5.5: 5.4$$

Sample Isotope	662-3	662-7	663-6	663-8	665-2	666-3	666-1
Ti 46	<b>9.1(5)</b>	<b>9.7(5)</b>	7.2(4)	8.1(4)	8.5(5)	<b>10.8(6)</b>	7.8(4)
Ti 47	<b>8.3(4)</b>	<b>8.6(5)</b>	6.5(4)	7.2(4)	7.8(4)	<b>10.1(5)</b>	7.6(4)
Ti 48	70(3)	<b>68(3)</b>	76(3)	73(3)	72(3)	<b>65(3)</b>	74(3)
Ti 49	<b>6.4(4)</b>	<b>6.9(4)</b>	5.4(3)	5.9(4)	5.9(3)	<b>7.2(4)</b>	5.4(3)
Ti 50	6.2(4)	<b>6.8(4)</b>	4.9(3)	5.8(4)	5.8(3)	<b>6.9(4)</b>	5.2(3)

Table 2b. Elements composition of samples, MSA, mass. %.

sample element	662-3	662-7	663-6	663-8	665-2	666-3	666-1
Na	<b>14.0(7)</b>	<b>6.8(4)</b>	<b>1.12(6)</b>	.10(1)	2.1(1)	<b>.48(3)</b>	<b>.52(3)</b>
Al	<b>2.2(1)</b>	<b>1.19(6)</b>	<.09(1)	<.030(6)	<.30(2)	<.20(2)	<.10(1)
Si	<.18(2)	<.09(1)	<b>.11(1)</b>	<b>.032(6)</b>	1.00(6)	<b>.38(3)</b>	<b>.63(4)</b>
P						<b>.07(1)</b>	
K		<b>.91(5)</b>	<b>.09(1)</b>	<b>.021(5)</b>	.032(6)	<b>.019(5)</b>	<b>.043(7)</b>
Ca		<b>1.7(1)</b>	<b>.41(3)</b>	<b>.11(1)</b>	.07(1)	<b>.031(6)</b>	<b>.062(8)</b>
Ti	33(2)	31(2)	98(1)	99(1)	7.1(3)	4.2(2)	6.8(3)
Mn	<b>.19(2)</b>	<b>.25(2)</b>	.005(2)	.005(2)	.22(2)	.0006(5)	0.002(1)
Fe	<b>2.2(1)</b>	.66(4)	.19(2)	.18(2)	<b>5.1(3)</b>	<b>.029(6)</b>	<b>.063(8)</b>
Ni	<b>2.8(1)</b>	<b>.33(2)</b>	.010(3)		30(1)	<b>.018(5)</b>	<b>.060(8)</b>
Cu	°	°	°	°	<b>.031(6)</b>	°	<b>.012(3)</b>
Zn	°	°	°	°	°	°	°
Zr	°	°	°	°	°	°	°
Nb					<b>.028(6)</b>		
Mo					.72(4)		
Ag			<b>&lt;.020(5)</b>	<.005(2)	<.003(1)	<.001(1)	<.010(3)
Sn			<b>&lt;.030(6)</b>	<.005(2)	<.005(2)	<.001(1)	<.020(5)
Sb			<b>&lt;.020(5)</b>	<.005(2)	<.003(1)	<.001(1)	<.010(3)
Ba			<.010(3)	<.005(2)	<.003(1)	<.001(1)	<.010(3)
Ta	44(2)	56(3)	<.010(3)	<.010(3)	54(2)	18(1)	16(1)
Au			<.020(5)	<.010(3)	<.005(2)	<.002(1)	<.010(3)
Pb				<.020(5)		77(3)	75(3)

Table3a. Isotope composition of the titan present in samples, MSA, mass. %.

 $^{46}\text{Ti}: ^{47}\text{Ti}: ^{48}\text{Ti}: ^{49}\text{Ti}: ^{50}\text{Ti} = 8.0: 7.3: 73.8: 5.5: 5.4$ 

Sample Isotope	415	453	668-8	669-4	669-8	670-8	foil Ti№1
Ti 46	8.1(4)	7.9(4)	8.2(4)	8.2(4)	8.6(5)	8.1(4)	8.1(4)
Ti 47	7.4(4)	7.2(4)	7.0(4)	7.9(4)	8.0(4)	7.4(4)	7.5(4)
Ti 48	73(3)	75(3)	74(3)	71(3)	71(3)	73 (3)	74(3)
Ti 49	5.8(3)	5.1(3)	5.5(3)	<b>7.1(4)</b>	5.9(3)	5.8(3)	5.3(3)
Ti 50	5.7(3)	4.8(3)	5.3(3)	5.8(3)	<b>6.5(4)</b>	5.7(3)	5.1(3)

Table 3b. Elements composition of samples, MSA, mass. %.

sample element	415	453	668-8	669-4	669-8	670-8
Na	<b>.38(3)</b>	<b>.10(1)</b>	<b>.32(2)</b>	<b>.21(2)</b>	<b>.38(3)</b>	<b>3.2(2)</b>
Al	<b>.72(4)</b>	<.06(1)	<b>.47(3)</b>	<b>.21(2)</b>	<.10(1)	<b>.57(4)</b>
Si	<b>.41(3)</b>	<b>.32(2)</b>	<b>.78(5)</b>	<b>1.12(6)</b>	<b>3.2(1)</b>	<b>1.03(6)</b>
K	<b>.05(1)</b>	<b>.019(5)</b>	<b>.021(5)</b>	<b>.031(6)</b>	<b>.018(5)</b>	<b>.18(2)</b>
Ca	<b>.20(2)</b>	<b>.032(6)</b>	<b>.033(6)</b>	<b>.047(7)</b>	<b>.037(7)</b>	<b>.33(2)</b>
Ti	99(-1)	7.2(3)	19(1)	10.9(6)	9.9(5)	16.8(8)
Cr		°				
Mn	<b>.020(5)</b>	<b>.012(3)</b>	.003 (1)	.006 (2)	.003(1)	.005(2)
Fe	.13(1)	<b>.028(6)</b>	.039(7)	<b>.22(2)</b>	.048(7)	<b>.22(2)</b>
Co		.041(7)				
Ni	<b>.08(1)</b>	91(4)	<b>.022(5)</b>	<b>.12(1)</b>	<b>.051(7)</b>	<b>.10(1)</b>
Cu	°	<b>.010(3)</b>	°	°	<b>.012(3)</b>	°
Zn	°		°	°	°	°
Zr		<b>.21(5)</b>	°	°	°	°
As		°				
Nb	°	<b>.003(1)</b>				
Mo		°				
Ag	<b>&lt;.010(3)</b>	<b>0.39(3)</b>	<.010(3)	<.010(3)	<.006(2)	<.010(3)
Sn	<b>&lt;.010(3)</b>	<b>&lt;.020(5)</b>	<.020(5)	<.020(5)	<.010(3)	<.020(5)
Sb	<b>&lt;.010(3)</b>	<b>&lt;.010(3)</b>	<.010(3)	<.010(3)	<.006(2)	<.010(3)
Ba	<b>&lt;.010(3)</b>	<b>&lt;.010(3)</b>	<.010(3)	<.01	<.006(2)	<.010(3)
Ta	<b>.020(5)</b>	<b>&lt;.010(3)</b>	15.0(7)	31(1)	21(1)	12.8(6)
W		°				
Au	<.010(3)	<.010(3)	<.010(3)	<.010(3)	<.006(2)	<.010(3)
Pb	<b>.007(2)</b>		64(3)	57(3)	66(3)	64(3)

Table 4. Elements composition of samples of foils, MSA, mass. %.

sample element	Ti №1	Ta	Pb	Ni
Na	<0.040(6)	<0.001(1)	<0.006(2)	0.004(1)
Al	<0.002(1)	<0.002(1)	<0.007(2)	< 0.010(3)
Si	<0.007(2)	<0.003(1)	<0.008(3)	<0.07(1)
K			<0.010(3)	<0.002(1)
Ca			<0.010(3)	<0.001(1)
Ti	99(-1)	<0.002(1)		< 0.010(3)
V				<0.001(1)
Cr				0.031(6)
Mn	0.003(1)	<0.002(1)	<0.010(3)	0.48(3)
Fe	0.21(2)	<0.002(1)	<0.010(3)	11.3(5)
Co				0.052(7)
Ni	0.030(6)	<0.003(1)		86(4)
Cu				0.08(1)
As				0.004(1)
Nb				0.001(1)
Mo				2.1(1)
Ag	<0.002(1)	<0.005(2)	<0.030(6)	
Sn	<0.004(1)	<0.010(3)	<0.060(8)	
Sb	<0.002(1)	<0.005(2)	<0.030(6)	
Ba	<0.002(1)	<0.005(2)	<0.030(6)	
Ta		>99.9(-1)	<0.040(7)	
W				0.010(3)
Au	<0.004(1)	<0.015(3)	<0.060(8)	
Pb			>99.7(-2)	

Table5. Elements composition of samples, XFA, mass.%, Ti in: H<sub>2</sub>O<sub>2</sub>+He,H<sub>2</sub> and H<sub>2</sub>O

	Foil Ti №1	Ti electrode	H <sub>2</sub> O <sub>2</sub> + He,H <sub>2</sub>	distilled water .			
			415	414	663-1	663-2	663-3
mg→	21.33	107.5	30.2	50.4	4.8	0.75	7.9
Ti	99.9(1)	99.7(3)	99.7(2)	99.7(3)	99.6(4)	99(1)	99.7(3)
Mn	≤.0001*	<b>.007(1)*</b>	°	<b>.014(3)</b>	<b>.014(3)</b>		°
Fe	.040(3)	.23(1)	.093(5)	.087(4)	.19(1)	.54(5)	.137(7)
Ni	.0085(5)	.032(3)	.037(2)	.051(2)	.040(4)		.037(3)
Cu	.0026(3)	.022(2)	<b>.039(2)</b>	<b>.049(2)</b>	.026(3)		.012(2)
Zn	≤.001	.016(2)	<b>.036(1)</b>	<b>.043(2)</b>	.009(2)		.015(2)
Y	≤.0003	≤.0003	<b>.0011(2)</b>				
Zr	.0006(2)	.0014(2)	<b>.0425(5)</b>	°	°		°
Nb	.0006(2)	≤.0003	.0010(2)	°	°		°
Mo	≤.0004	≤.0004		<b>.0121(2)</b>			
In	≤.003	≤.003			<b>.0050(5)</b>		<b>.0050(5)</b>
Sn	≤.003	≤.003	<b>.0059(6)</b>				
Sb	≤.001	≤.001	<b>.0040(4)</b>		<b>.0040(4)</b>		<b>.0058(6)</b>
Pb	≤.001	≤.001	<b>.016(1)</b>	<b>.041(1)</b>	<b>.007(2)</b>		<b>.011(1)</b>
	Foil Ti №1	Ti electrode	distilled water				
			663-4	663-5	663-6	663-7	663-8
mg→	21.33	107.5	6.8	7.79	6.7	7.1	9.12
Ti	99.9(1)	99.7(3)	99.8(1)	99.8(1)	99.8(1)	99.8(1)	99.8(1)
Mn	≤.0001*	<b>.007(1)*</b>	°	<b>.026(9)</b>	°	<b>.035(8)</b>	<b>.049(8)</b>
Fe	.040(3)	.23(1)	.15(1)	.079(7)	.13(2)	.113(7)	.097(6)
Ni	.0085(5)	.032(3)	.007(2)	.011(2)	.039(3)	.029(3)	.015(2)
Cu	.0026(3)	.022(2)	.007(2)	.011(2)	.016(2)	.016(2)	.014(2)
Zn	≤.001	.016(2)	.011(1)	.011(1)	.016(2)	.009(1)	.021(1)
Y	≤.0003	≤.0003					
Zr	.0006(2)	.0014(2)	°	°	°	°	°
Nb	.0006(2)	≤.0003	°	°	°	°	°
In	≤.003	≤.003					.0040(4)
Sn	≤.003	≤.003	<b>.0046(4)</b>	<b>.0075(7)</b>			
Sb	≤.001	≤.001	<b>.0068(7)</b>	<b>.014(1)</b>		<b>.011(1)</b>	<b>.0080(7)</b>
Pb	≤.001	≤.001		<b>.006(1)</b>	<b>.007(1)</b>	<b>.0045(9)</b>	<b>.009(1)</b>

\* - The result received by the neutron activation analysis



Table 6. Elements composition of samples, XFA, mass. %, Ti in glycerin

sample element	Foil Ti №2	Ti electrode	660	661	664	671-7
Ti	99.9(2)	99.7(3)	96.3(6)	94 (2)	98(1)	96(1)
Mn	$\leq 2 \cdot 10^{-6}$ *	0.007(1) *	°	<b>0.6(2)</b>	<b>0.28(6)</b>	<b>0.8(1)</b>
Fe	0.038(2)	0.23(1)	<b>0.80(8)</b>	<b>0.9(1)</b>	<b>0.60(4)</b>	<b>1.2(1)</b>
Ni	0.007(1)	0.032(3)	<b>1.2(1)</b>	<b>0.44(7)</b>	<b>0.18(2)</b>	<b>0.83(5)</b>
Cu	0.006(2)	0.022(2)	<b>0.83(5)</b> (Cu +Zn)	<b>3.4(1)</b> (Cu +Zn)	<b>0.27(2)</b>	<b>0.84(4)</b> (Cu +Zn)
Zn	0.002(1)	0.016(2)			<b>0.10(1)</b>	
Zr	0.0009(5)	0.0014(2)	°	°	°	°
Nb	0.0009(5)	$\leq 0.0003$	°	°	°	°
Pb	0.0003(2)	$\leq 0.001$	<b>0.8(4)</b>	°	°	°

\*- The result received by the neutron activation analysis

Table 7. Elements composition of samples, XFA, mass. %, Ta + (Fe-Ni) in H<sub>2</sub>O<sub>2</sub> 1%:

	Ta foil	Fe-Ni foil	Ti electrode.	665-2	665-4	665-6	665-8
Ti			99.7(3)	10.7(2)	8.8(2)	11.6(3)	14.6(3)
Mn	.005*	1.60(5)	0.007(1)*	0.76(6)	<u>0.35(4)</u>	0.70(3)	<u>0.39(4)</u>
Fe	.93(6)	37.1(2)	0.23(1)	<u>8.50(8)</u>	<u>8.9(1)</u>	<u>8.19(8)</u>	<u>8.0(1)</u>
Ni	$\leq 0.003$ ***	59.8(1)	0.032(3)	25.1(1)	28.3(1)	26.0(1)	26.9(1)
Cu			0.022(2)		°		°
Zn			0.016(2)		°		°
Zr			0.0014(2)		°		°
Nb	.027(1)			0.015(1)	0.013(1)	0.019(1)	0.013(1)
Mo	$\leq 0.002$	1.50 (1)	$\leq 0.001$	0.466(3)	0.430(4)	0.498(3)	0.420(4)
Sb	$\leq 0.002$ **	$\leq 0.006$ **	$\leq 0.003$ **		<b>0.012(1)</b>		<b>0.010(1)</b>
Ta	99.0(2)			55.2(1)	53.2(1)	52.7(1)	49.6(1)

\* - The result received by the neutron activation analysis

\*\* - The result received by the gamma activation analysis

\*\*\* - The result received by mass spectrometric analysis

Table 8. Elements composition of samples, XFA, mass.%. Ta in H<sub>2</sub>O and Ta+Pb in H<sub>2</sub>O<sub>2</sub>

	Ta foil	Pb foil	Ti electrode	H <sub>2</sub> O		number of samples (H <sub>2</sub> O <sub>2</sub> in %).		
				662-3	662-7	668-8 H <sub>2</sub> O <sub>2</sub> 1%	669-4 3%	669-8 3%
Ti			99.7(3)	58.2(7)	46.8(5)	10.2(3)	6.9(2)	12.8(3)
Mn	≤.005*	≤.0006*	.007(1)*	°	°	<b>.18(2)</b>	°	<b>.26(5)</b>
Fe	0.93(6)	.78(9)	.23(1)	.57(5)	.87(4)	.73(4)	.59(4)	.54(4)
Ni	≤.003***		.032(3)	<b>.12(2)</b>	<b>.19(2)</b>	°	°	°
Cu		.22(3)	.022(2)	°	°	°	°	°
Zn			.016(2)	°	°	°	°	°
Zr			.0014(2)	°	°	°	°	°
Nb	.027(1)			.015(2)	.019(1)	.016(1)	.016(1)	.011(1)
Mo	≤.002	≤.001	≤.001		<b>.009(1)</b>	.004(1)		.002(1)
Sb	≤.002**	≤.004**	≤.003**			<b>.006(1)</b>	<b>.006(1)</b>	<b>.008(1)</b>
Ta	99.0(2)			41.1(2)	52.1(2)	59.6(2)	64.7(2)	58.3(2)
Pb		99.0(2)		<b>.021(7)</b>		29.2(1)	27.5(1)	27.4(1)
	Ta foil	Pb foil	Ti electrode	number of samples (H <sub>2</sub> O <sub>2</sub> in %)				
				670 10%	666-1 1 %	666-3 1 %	666-5 1 %	666-8 1 %
Ti			99.7(3)	8.8(3)	5.2(2)	9.1(3)	7.0(3)	7.2(3)
Mn	≤.005*	≤.0006*	.007(1)*	<b>.40(5)</b>	<b>.39(5)</b>	<b>.53(5)</b>	°	°
Fe	0.93(6)	.78(9)	.23(1)	.47(5)	.51(3)	.81(5)	.48(4)	.48(4)
Ni	≤.003***		.032(3)	°	°	°	<b>.05(2)</b>	<b>.05(2)</b>
Cu		.22(3)	.022(2)	°	°	°	°	°
Zn			.016(2)	°	°	°	°	°
Zr			.0014(2)	°				
Nb	.027(1)			.016(1)	.010(1)	.015(1)	.016(1)	.012(1)
Mo	≤.002	≤.001	≤.001	.002(1)				
Sb	≤.002**	≤.004**	≤.003**	<b>.010(1)</b>	.002(1)		<b>.015(1)</b>	<b>.007(1)</b>
Ta	99.0(2)			57.1(2)	55.5(1)	49.1(1)	54.9(2)	51.8(2)
Pb		99.0(2)		33.2(1)	38.4(1)	40.5(1)	37.6(1)	40.4(1)

\* - The result received by the neutron activation analysis;

\*\* - The result received by the gamma activation analysis

\*\*\* - The result received by mass spectrometric analysis

Table 9. Elements composition of samples, received by the neutron- and gamma activation analysis (g/g).

sample	Ti №1	Ti №2	Ti el.	414	415	663-123	663-4	663-7
mg →	26.8	25.8	107.5	30.2	50.4	20.6	7.2	12.9
Al (n,γ)	≤ 4·10 <sup>-4</sup>	≤ 4·10 <sup>-4</sup>	3.2(2)·10 <sup>-3</sup>	2.1(4)·10 <sup>-3</sup>	3.0(3)·10 <sup>-3</sup>	1.7(4)·10 <sup>-3</sup>		
Na (n,γ)	≤ 5·10 <sup>-4</sup>	≤ 5·10 <sup>-4</sup>	≤ 5·10 <sup>-5</sup>	<b>4.7(4)·10<sup>-3</sup></b>	<b>2.5(2)·10<sup>-3</sup></b>	<b>6.9(4)·10<sup>-3</sup></b>		
Cl (γ,n)	≤ 10 <sup>-5</sup>	≤ 10 <sup>-5</sup>	≤ 10 <sup>-5</sup>	<b>6.4(5)·10<sup>-4</sup></b>	<b>7.5(7)·10<sup>-4</sup></b>	<b>9.7(7)·10<sup>-4</sup></b>	<b>1.5(2)·10<sup>-3</sup></b>	<b>5.6(7)·10<sup>-4</sup></b>
Mn (n,γ)	≤ 10 <sup>-6</sup>	≤ 2·10 <sup>-6</sup>	7(1)·10 <sup>-5</sup>	<b>3.1(1)·10<sup>-4</sup></b>	<b>2.3(1)·10<sup>-3</sup></b>	<b>5.7(1)·10<sup>-4</sup></b>		
Sb (n,γ)	≤ 5·10 <sup>-5</sup>	≤ 5·10 <sup>-5</sup>	≤ 3·10 <sup>-5</sup>	<b>2.0(2)·10<sup>-3</sup></b>	<b>6(1)·10<sup>-4</sup></b>	<b>4(1)·10<sup>-3</sup></b>		
Sb (γ,n) 564 keV				<b>1.05(5)·10<sup>-3</sup></b>	<b>5.6(2)·10<sup>-4</sup></b>	<b>1.2(1)·10<sup>-3</sup></b>	<b>3.4(1)·10<sup>-3</sup></b>	<b>1.5(1)·10<sup>-3</sup></b>
Sb (γ,n) 1171keV				<b>9(1)·10<sup>-4</sup></b>	<b>5.5(4)·10<sup>-4</sup></b>	<b>1.2(1)·10<sup>-3</sup></b>	<b>2.5(2)·10<sup>-3</sup></b>	<b>1.4(1)·10<sup>-3</sup></b>
sample	Ti el.	Ta	Pb		666-1	668	669-4,8	670-8*
mg →	107.5	67.3	59.5		25.4	76.5	102.9	32.5
Al (n,γ)	3.2(2)·10 <sup>-3</sup>	≤ 10 <sup>-4</sup>	≤ 10 <sup>-4</sup>		4.7(6)·10 <sup>-3</sup>	5(2)·10 <sup>-4</sup>	6(1)·10 <sup>-4</sup>	
Na (n,γ)	≤ 5·10 <sup>-5</sup>	≤ 10 <sup>-4</sup>	≤ 2·10 <sup>-4</sup>		<b>2.5(4)·10<sup>-3</sup></b>	<b>1.1(1)·10<sup>-3</sup></b>	<b>2.4(1)·10<sup>-3</sup></b>	<b>8.6(4)·10<sup>-3</sup></b>
Cl (γ,n)	≤ 10 <sup>-5</sup>	≤ 10 <sup>-5</sup>	1.5(4)·10 <sup>-5</sup>		<b>8.7(5)·10<sup>-4</sup></b>	<b>3.3(3)·10<sup>-4</sup></b>	<b>2.1(1)·10<sup>-5</sup></b>	
Mn (n,γ)	7(1)·10 <sup>-5</sup>	≤ 5·10 <sup>-5</sup>	≤ 6·10 <sup>-6</sup>		<b>1.3(1)·10<sup>-4</sup></b>	<b>6.6(2)·10<sup>-5</sup></b>	<b>9.7(2)·10<sup>-4</sup></b>	<b>1.7(1)·10<sup>-4</sup></b>
Sb (n,γ)	≤ 3·10 <sup>-5</sup>	≤ 10 <sup>-4</sup>	≤ 4·10 <sup>-5</sup>		<b>1.0(3)·10<sup>-3</sup></b>	<b>4(1)·10<sup>-4</sup></b>	<b>8(1)·10<sup>-4</sup></b>	<b>1.3(2)·10<sup>-3</sup></b>
Sb (γ,n) 564 keV		≤ 2·10 <sup>-5</sup>	≤ 10 <sup>-4</sup>		<b>8.7(4)·10<sup>-4</sup></b>	<b>1.1(1)·10<sup>-3</sup></b>	<b>1.0(1)·10<sup>-3</sup></b>	<b>1.1(1)·10<sup>-3</sup></b>
Sb (γ,n) 1171keV					<b>6.2(5)·10<sup>-4</sup></b>	<b>1.2(1)·10<sup>-3</sup></b>	<b>8.7(7)·10<sup>-4</sup></b>	<b>8.1(7)·10<sup>-4</sup></b>

\* - Measurements were carried after mass spectrometric analysis, the sample was cleaned off from an aluminium substrate.

Table 10. Elements composition of sample №453 , received by the different methods of analysis Ni in distilled water.

	Ti	Mn	Fe	Ni	Cu	Y	Zr	Ag	Sb	Ba	Pb
XFA, %	14.2 (2)		<u>.41</u> (3)	85.2 (1)		<b>.003</b> <b>(1)</b>	<b>.176</b> <b>(2)</b>	<b>.266</b> <b>(3)</b>	<b>.011</b> <b>(1)</b>	<b>.006</b> <b>(2)</b>	<b>.029</b> <b>(3)</b>
MCA, %	7.2 (3)	.012 (3)	<u>.028</u> (6)	91 (1)	<u>.010</u> (3)		<b>.21</b> <b>(5)</b>	<b>.39</b> <b>(3)</b>	<b>&lt;.010</b> <b>(3)</b>	<b>≤.010</b> <b>(3)</b>	
* NAA, GAA,%	20 (2)	.20 (1)		78 (1)				<b>1.2</b> <b>(2)</b>	<b>1.0</b> <b>(1)</b>		

\*- activation was carried after MSA, the sample was cleaned off from an Al substrate

Table 11. The content of admixtures in water.

Element	Abundance, 10 <sup>-8</sup> g/g
Al	0.72
Si	5.65
K	37.48
Ca	38.98
Ti	0.050
Mn	0.11
Fe	3.49
Co	0.005
Ni	0.035
Cu	0.53
Zn	0.497
Cd	0.026
Pb	0.045

Table.12. The content of admixtures in glycerin (C<sub>3</sub>H<sub>8</sub>O<sub>3</sub>).

Element	Abundance 10 <sup>-6</sup> g/g
Cl	1
S	5
Fe	0.5
As	0.4
Pb	0.5

Table 13. The content of admixtures in polyethylene.

Element	Abundance weight %
C	99.78134
F	.000086
Na	.020299
Mg	.001149
Al	.141150
Si	.03327
P	.001712
S	.002041
Cl	.004141
K	.006613
Ca	.004404
Ti	.000051
V	.000003
Cr	.000170
Mn	.000229
Fe	.002007
Co	.000035
Ni	.000329
Cu	.000224
Zn	.000676
Sr	.000044
Ba	.000028

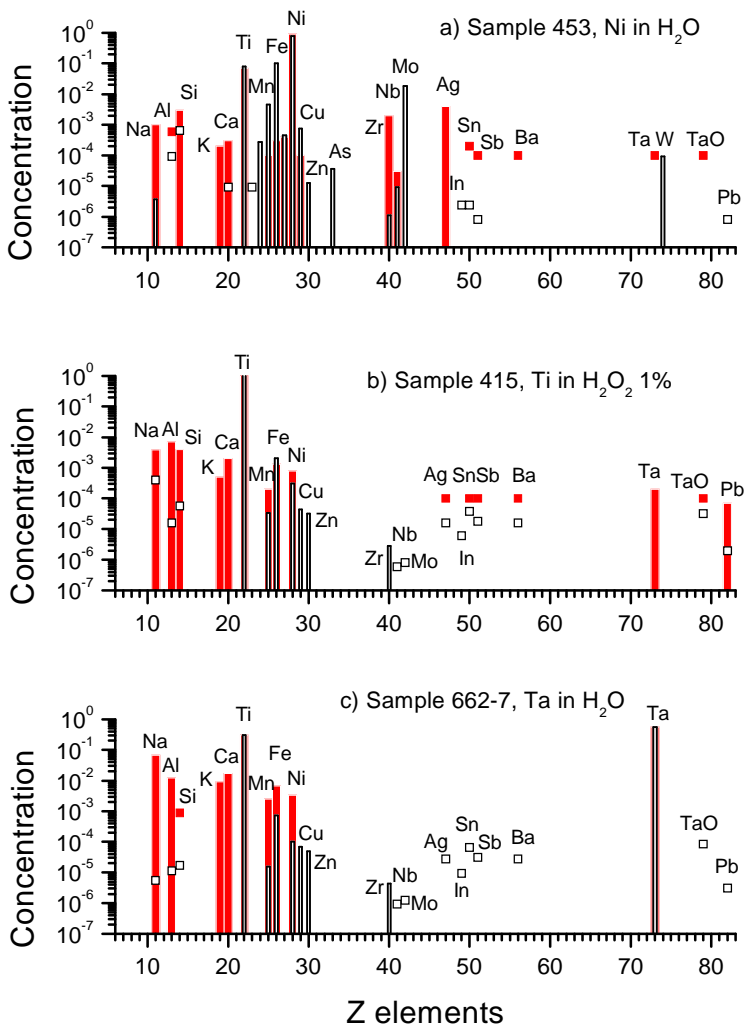


Fig. 9. Element composition of samples, measured by MSA technique: a) sample 453, load – Ni, distilled water as medium; b) sample 415, load –Ti, medium – H<sub>2</sub>O<sub>2</sub> (1%); c) sample 662-7, load – Ta, distilled water as medium.

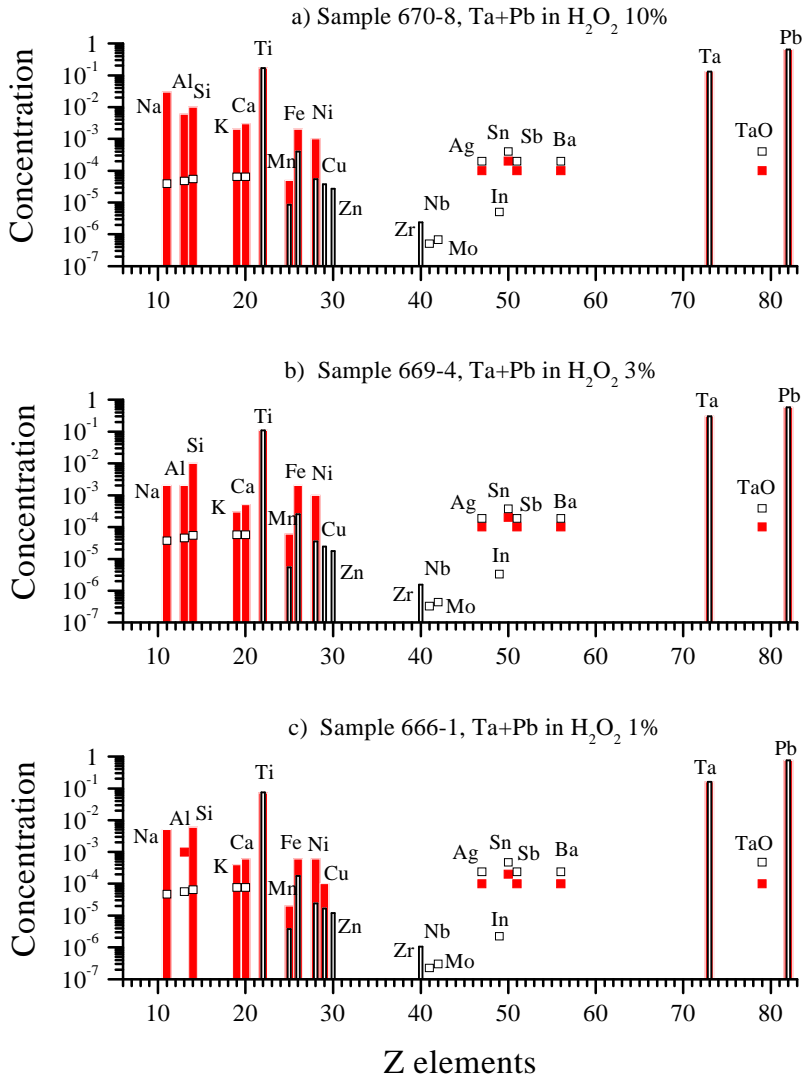


Fig. 10. Element composition of samples, measured by MSA technique: a) sample 670, load–Ta+Pb, medium –H<sub>2</sub>O<sub>2</sub> (10%); b) sample 669-4, load– Ta+Pb, medium – H<sub>2</sub>O<sub>2</sub> (3%); c) sample 666-1, load – Ta+Pb, medium - H<sub>2</sub>O<sub>2</sub> (1%);

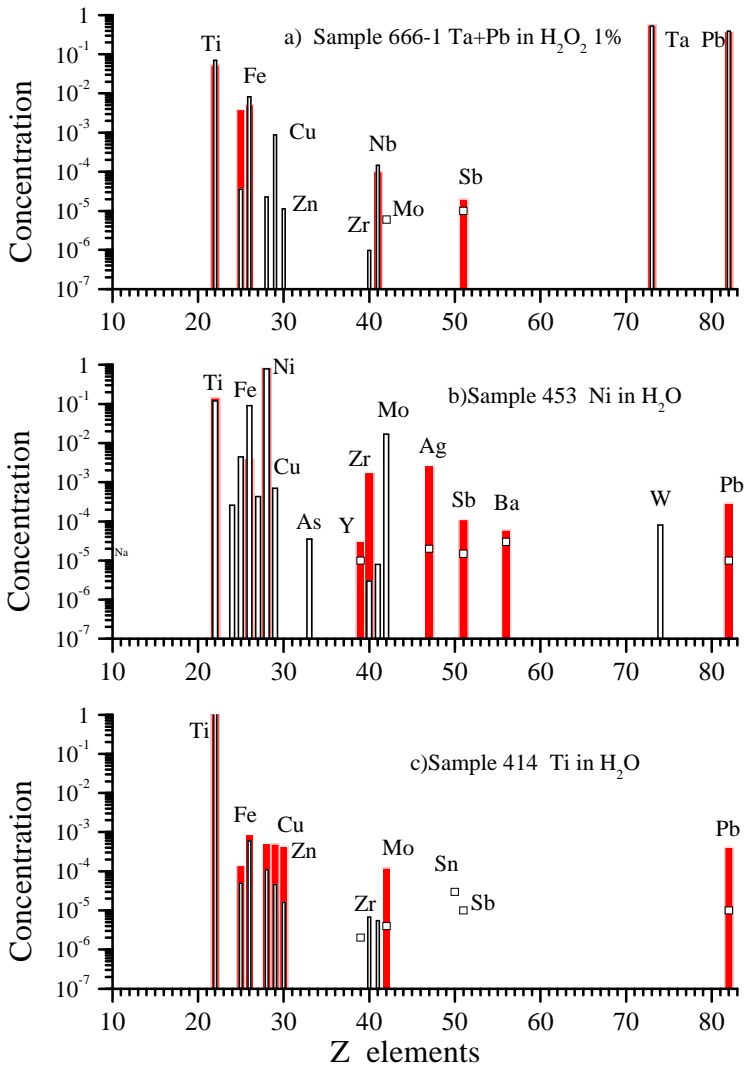


Fig. 11. Element composition of samples, measured by XFA technique: a) sample 661, load– Ta+Pb, medium -  $H_2O_2$  (1%); b) sample 453, load – Ni, distilled water as medium; c) sample 414, load – Ti, distilled water as medium.

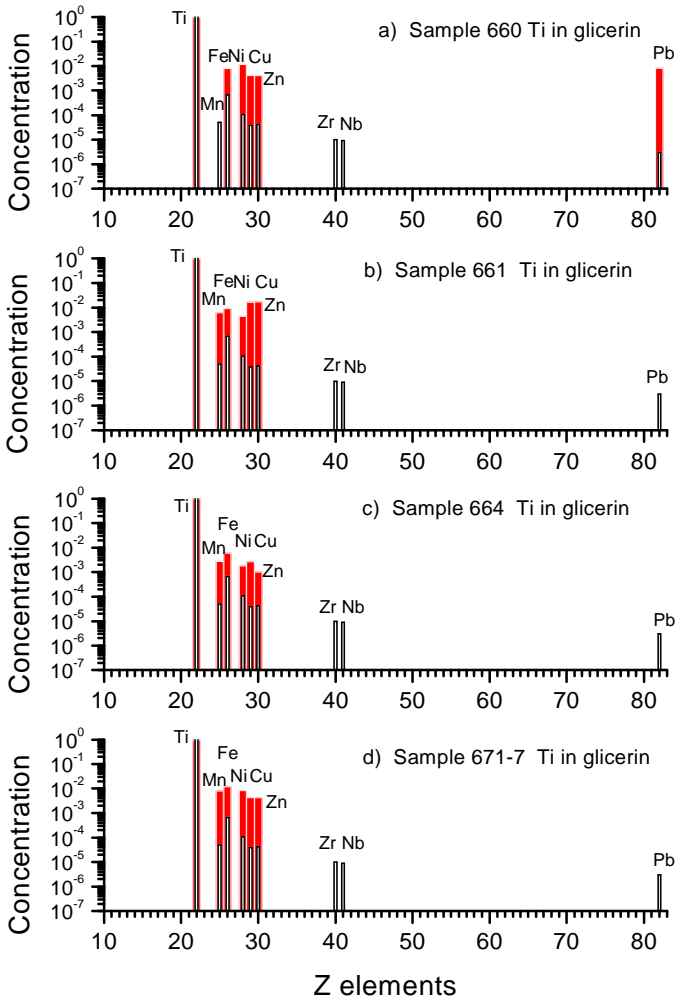


Fig. 12. Element composition of samples, measured by XFA technique, medium – glycerin, load –Ti: a) sample 660; b)sample 661; c)sample 664; d)sample 671-1.



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