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THE KIEV EXPERIMENTS ON LOW ENERGY NUCLEOSYNTHESIS

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The physicists of the Kiev "Proton-21" laboratory (www.proton21.org.ua) of low energy nuclear physics (Dr. S. Adamenko and coworkers) claim evidence (through 5000 experiments, carried out since 1999) for an enormous number of "low energy nucleosynthesis" in a little ball of copper invested from all sides by 0.3 MeV electrons. The elemental and isotopic analysis of the reaction products done in Kiev was confirmed in laboratories of other countries (USA, Russia).

Starting from a 99.99 % pure ball of copper (0.01 % impurities), a large quantity of elements like O, K, La, Ce, Pt, Pb was produced. The total number of new nuclei is comparable with the total number of initial copper nuclei. The process has further amazing features:

1) the radioactivity of the resulting material is not different from the background activity,
2) transuranic nuclei are produced, including superheavy ones.

The aim of the workshop is to present for the first time the Kiev results and discuss their significance, meaning and possible applications (e.g. energy producing, eliminating of radioactive wastes).

Organizing Committe:

Prof. S. Albeverio,
Prof. Yu. Kondratiev,
Prof. F. Selleri,
Prof. V. Jentsch.

Conception of the artificially initiated collapse of the substance and key results of the first stage of its experimental implementation

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Briefly described is the author's conception of shock coherent collective cascaded cumulative mechanism of particles acceleration through initiating the self-developing collapse of a converging solitary shell-wave of extreme density of energy and substance. Also provided is some part of experimental data obtained in course of practical implementation of that concept. The paper is aimed at preliminary discussion of the composition and content of collected works describing the experimental and theoretical results obtained in the Electrodynamics Laboratory of Proton-21 company in Kiev, Ukraine. This work has been carried out within the commercial project called Luch, which is developed on our initiative and aims at the creation of new, efficient and environmentally safe nuclear technologies for neutralizing the radioactivity and synthesizing stable isotopes of chemical elements, including superheavy ones.

Key results of analytic studies of the laboratory nucleosynthesis products

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In order to confirm the fact of nuclear reactions running, we posed, as the principal task for the samples surface studies, both the detection of elements which were absent in the materials prior to the experiment and the establishment of discrepancies between the isotope composition observed and that in the nature for individual elements.

As the main method for local analyses, we chose X-ray electron probe microanalysis. Special attention was given to the detection of elements rarely observed in nature. Of great interest were also the inclusions containing the great number of different chemical elements, from the lightest to the heaviest ones.

The isotope composition of elements was studied by mass-spectrometry on these devices: SIMS Cameca IMS-4F, Finnigan MAT-262, TOF-SIMS, VG-9000, MI-1201, and a laser mass-spectrometer constructed at Kiev University.

To study the gaseous component, we took gas samples from the hermetic reaction chamber. With this method, we eliminate an otherwise possible isotope separation of elements. In the samples taken after successful experiments, we revealed regularly the presence of argon with an unnatural isotope composition.

Studies of samples using analytical chemistry methods showed the presence of different rare elements including the elements of lanthanide series absent in the samples before the experiment.

The results clearly show the following:

- essential increase in the concentrations of all studied chemical elements;
- concentrations of synthesized elements are essentially higher in the central parts of accumulating screens;
- number of synthesized atoms in a single experiment exceeds 1×10^{18}.

Of special interest is the fact that in this whole variety of created isotopes, there are no radioactive ones present.

This became the reason for the execution of experiments aimed at the neutralization of radioactivity. Measurements of the radioactivity of the chamber before and after the experiments proved its regular decrease by 10 to 38% under successful explosions of a target.

While investigating the samples with various mass-spectrometry methods, we were always paying attention to the registration of peaks related to masses more than 210, which cannot be referred to the signals from molecular compounds or clusters. By laser mass-spectrometry, we studied some peaks with masses up to 6300.

The scientific-industrial concern Luch (Russia), which studied some samples using Finnigan MAT-262 thermal ion mass-spectrometer, issued a conclusion stating that they found in the mass spectra the following masses, which could not be interpreted and identified: 253, 264, 278, 280, 394, 395, 433, 434. Analogous results were obtained when studying the samples using Cameca IMS-4F secondary-ion mass-spectrometer.

Presence of superheavy chemical elements on surface of accumulating screens is also supported with the results received using devices, which allow direct investigation of the electron shell of atom. The X-ray electron probe, X-ray fluorescence and Auger-spectrometry studies carried out have shown the presence in spectra of individual samples of peaks which do not belong to known chemical elements, nor are they artefacts of the analysis.

Superheavy elements searching in the products of laboratory nucleosynthesis using Rutherford backscattering of α-particles and $^{14}N^{++}$

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During the last three decades, superheavy atomic nuclei with masses up to 10^7 were intensively searched. Such unusual atomic nuclei can exist as relict objects appeared at early stages of the formation of the observable Universe and as the products of unsteady nuclear processes occurring in a superdense matter. But all the attempts to find them failed.

One of the methods of creation of superheavy atomic nuclei is the fusion reactions of heavy ions, e.g., $^{48}Ca + {}^{248}Cm$ and $^{48}Ca + {}^{244}Pu$ with the formation of highly excited systems $^{288}(Z = 144)$ and $^{296}(Z = 116)$ with the excitation energy E^* = 36…37 MeV. This method of synthesis of superheavy elements has an undesirable aspect, namely the high excitation energy of an intermediate compound system and, as a consequence, the presence of a great number of decay channels for such a system. For this reason, the search for other fusion mechanisms to create the "cold" compound nuclei is of independent interest.

The Electrodynamics Laboratory Proton-21 constructed a laboratory setup for the inertial nucleosynthesis capable to get experimentally self-compressing plasma bunches with a density of > 10^{26} nucleon/cm^3. The products of laboratory nucleosynthesis revealed the presence of elements in the transmuted substance with atomic masses 2, 3, 5, and more times that of the elements originally contained in the targets. This provided us with grounds to suppose that using heavy elements for targets, such as Au, W, or Pb, accordingly it would be possible to find among products of the synthesis superheavy elements with atomic masses up to 10^3 and more. First evidences of the presence of superheavy nuclei were obtained with different mass-spectrometric methods.

We used the method of Rutherford backscattering of α-particles and ions ^{14}N to study the composition of admixtures in the near-surface layers of targets.

In order to uniquely identify elastically scattered particles and the products of nuclear interactions, we used the (ΔE, E–ΔE) technique for α-particles with an energy of 27.2 MeV and the time-of-flight (E, T) method for ions ^{14}N with an energy of 8.7 MeV. The energy beam dispersion was 1 % of the nominal energy beam.

The obtained experimental data on the elastic scattering of α-particles with an energy of 27.2 MeV and ions $^{14}N^{++}$ with an energy of 8.7 MeV by the surfaces of accumulating screens indicate the events which can be referred, in the authors' opinion, to the processes of elastic scattering of ions ^{14}N and α-particles by superheavy nuclei (A = 310…4500).

The authors understand how strong is the assertion about the discovery of such stable nuclei and hope that the results presented here will be confirmed by subsequent experimental studies.

Investigation of the Coulomb excitation of decay modes of the metastable states of superheavy atomic nuclei (first experiments)

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The goal of the present work was in the development of a procedure of Coulomb excitation of the decay modes of the metastable states of atomic nuclei and in the ascertainment of the fact of the presence (or absence) of SHN in the specimens under study.

The specimens are accumulating screens, on which the target material undergone a nuclear transmutation precipitates after the explosion of a target. The products precipitated on accumulating screens are drops, splashes, films, granules, and other micro- and nanoobjects with complicated morphology, being irregularly distributed on the surface of screens.

The measurement of α-spectra of the specimens irradiated by low-energy Cu ions were carried out in the off-line mode on a VLADO unit with an α-spectrometer positioned in a low-noise lead casing. The energy resolution of the α-spectrometer was ΔE=16 keV on the lines of ^{226}Ra in the region E_α = 4…8 MeV. It is necessary noting that statistically significant events in the off-line mode were accumulated for 6…8 h. Then only the background events caused by high-energy cosmic-ray particles were registered.

The observed α-lines with energies: 6.48 MeV, 7.70 MeV, 7.83 MeV, 8.10 MeV, 8.24 MeV, 9.30 MeV, 10.20 MeV, 10.90 MeV and with the energy resolution ΔE=16 keV by α-lines allow us to assert that the surface of accumulating screens-targets contains the microscopic amounts of SHN which become α-emitters under their low-energy Coulomb excitation.

In view of the geometry of a detecting system and the period of α-decay of these amounts of SHN, we can estimate their number in microclusters.

We estimated the number of SHN in one atomic cluster as 500, and the surface of an accumulating screen contains up to 2000 clusters. The decay α-band (4…12 MeV) discovered in one of the experiments allows us to evaluate the parent nucleus mass as 1500…2000 a.m.u.

Based on the obtained results, we draw the following conclusions:

- We have registered superheavy atomic nuclei on the specimens whose surface contains the products of the explosion-induced destruction of a target after a high-energy explosive compression, which is confirmed by their induced fission,
- The discovered α-decay of superheavy atomic nuclei allows us to evaluate the parent nucleus mass as 1500…2000 a.m.u.

Key results of measurements of X-ray and optical radiation in the collapse area

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Presented here are results spectral measurements for the X-ray radiation of the "hot spot" in the energy range of 10 keV to 3–5 MeV, as well as optical radiation of the plasma bunch around the hot spot in the wavelength range of 300 to 500 nm.

Hot spot X-ray spectra in individual experiments were obtained solving the inverse problem from filtration curves measured using GaAs detectors equipped with sets of copper filters 20 micrometers to 11 mm thick. Measurements were done in the azimuthal plane at the distance of 23 cm from the hot spot, through the aluminium window 350 micrometers thick. Current signals from the detectors were registered with Tektronix fast oscilloscopes without preamplification. Also used in spectra reconstruction were data obtained from measurements done in the 10 to 88 keV energy range using Ross differential filters, and DK-02 dosimeters placed near GaAs detectors.

Averaged X-ray spectrum of the hot spot in the energy range of 10 keV to 3–5 MeV has been compared with spectra of some astrophysical objects, namely the Sun, Crab nebula pulsar, quasar 3C273, Supernova SN1987A, short-term gamma radiation bursts in the Universe, and bremsstrahlung spectrum from the electron beam hitting a massive target. As a measure of comparison, we used correlation coefficients for spectral flux density.

It has been shown that the hot spot radiation spectrum corresponds with high correlation coefficients to the spectra of astrophysical objects (quasar: correlation coefficient of 0.937; pulsar: 0.916; gamma burst: 0.989), and differs from the other objects' spectra (SN1987A: –0.231; the Sun: –0.955; bremsstrahlung: –0.243). A conclusion has been made that the hot spot radiation parameters in the energy range of 10 keV to 3–5 MeV are close to those of nonstationary astrophysical objects, which are distinct by a compact radiating area and the existence of considerable magnetic fields.

Optical radiation in the wavelength range of 300 to 500 nm was measured in the azimuthal plane, from the distance of ~6 m, through the 4 mm thick output window made of plexiglass, using a multichannel CCD-based system of optical spectra registration. In the near ultraviolet area calibration was done using the continuous spectrum of the DDS-80 deuterium lamp, and in the visible area it was done using the continuous spectrum of the tungsten incandescent lamp.

After computer processing using Peak Fit software, optical spectra were used to estimate the energy parameters of the plasma bunch corpuscular component. For the ion component, the energy parameters were estimated based on the analysis of the Gaussian components in spectral lines of separate ions of different chemical elements (from the Doppler broadening). The number of calculated radiating ions was estimated using the curves of integral absorption for spectral lines ("growth curves"). To estimate the electron concentration, we used the Lorentz components of the hydrogen spectral lines, assuming that the broadening is caused by the linear Stark effect under the electron action. The electron temperature was estimated directly from the amplitude of the H_α hydrogen line.

Parameters of the plasma corpuscular component have been compared for the successful experiment vs. the "dummy" imitation experiment:

- successful experiment: energy output for the ion component was 750 J, with the number of ions being 8×10^{17}, and their average energy of 9.4 keV; energy output for the electron component was ~60 J, the number of electrons being 1×10^{18}, and their temperature of ~0.36 keV;
- "dummy" imitation experiment: energy output for the ion component was ~8 J, with the number of ions being 1.6×10^{17}, and their average energy of 0.38 keV; energy output for the electron component was ~4 J, the number of electrons being ~3×10^{17}, and their temperature of ~0.08 keV.

Results of the optical spectra comparison between the successful experiment and dummy imitation demonstrate that energy parameters are significantly higher for processes occurring around the hot spot. They also indicate the presence within the spectrum of the hot spot plasma bunch of spectral lines of ions of some elements Fe, Ni, and other chemical elements, which were not contained in the original composition of the target material, but which compete, in terms of both energy and numbers of radiating atoms , with the basic elements of that material.

Track measurements of particle streams for the impulse discharge explosive plasma

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Presented here are experimental results of registration of fast particle tracks using CR-39 polymer track detectors exposed in the experiments where an impulse discharge was created in the device based on the relativistic vacuum diode. Those CR-39 track detectors prove to be good indicators of the characteristic effects in the target. When exposed to the open plasma stream, the detectors are completely filled with "plasma" tracks of ions with submicrometer and micrometer run lengths, which correspond to the particle energies of up to 100 keV per nucleon with the absolute track density of the order of 10^8 tracks/cm^2 (when exposed at the distance of 10 cm from the "hot spot"). This presentation is about analyzing the registration data for particles with run lengths in excess of 10 micrometers, and energies of the order of 1 MeV per nucleon, which belong to light nuclei and are registered under some (not always controllable) circumstances, either in the corpuscular streams radiated from the "hot spot", or as a result of aftereffects when the target is hit.

There are two categories of long-run tracks registered. The first one includes those nuclear tracks for which the track etching speed is similar or equal to that for alpha particles (the latter being known from the natural background observations. In those track aggregates, the number of tracks is up to 100/mm^2 per shot, the track orientation being unrelated to the center of the discharge, and track aggregates appearing in detectors *shadowed* from the direct plasma radiation. Such aggregates of nuclear tracks are, in turn, split into two types: 1) completely chaotic tracks, seen as a sharp increase in the alpha radiation background, with the main difference from that background being the fact that such increase is limited with the experiment time frame and appears locally; and 2) centered clusters of tracks, with the tracks in them clearly oriented towards the cluster's very own local spreading center. There are examples of both clusters with low number of tracks and a family of tracks from approximately 300 particles radiated simultaneously from one moving center. Analysis of the tracks shows that they belong to alpha particles with energies of about 5 MeV, as well as, probably, to lithium nuclei with energies of up to 8 MeV, or even heavier nuclei.

The other category is nuclear tracks which are created in controllable conditions, with the ability to reproduce them, by dense streams of fast particles coming from the "hot spot". Using ion pinhole cameras, we acquired the most contrast images of the "hot spot" carried by those particles, which appear as split spots of a certain shape. Track analysis allows unambiguous identification of those particles as hydrogen nuclei with run lengths from several micrometers to 30 micrometers. For additional identification of fast particles in those experiments, we used a test involving the gamma activation of a boride-carbon plate under the impact of those streams, which allows e.g. controlling of the presence of 400 keV protons accelerated by collective acceleration mechanisms in the same research setup, The absence of any gamma activity in the boride-carbon plate exposed together with the indicating detector in experiments with streams coming from an impacted target of a certain construction, as well as the absence of gamma activation of carbon contained in the CR-39 polycarbonate composition, allows the conclusion that in this case the corpuscular radiation is formed by deuterons. The deuterons fluence in those experiments (conventionally calculated for 4π) is estimated as up to 10^{11} particles per impulse, the maximum registered energy being 1.75 MeV.

The theory and model of realization of superheavy nuclei synthesis via the process of controlled electron-nuclear collapse

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The report presents a brief review of the existing approaches to the creation of abnormal and superheavy nuclei in collisions of usual nuclei to overcome the Coulomb barrier in the system of nuclei with a charge Z in the volume of neutralized relativistic degenerate electronic gas with high density n_e.

A fundamentally new approach to the creation of superheavy nuclei based on the stimulation of a self-organizing collapse of electron-nuclear systems is analyzed.

For a neutral atom compressed by external forces, a threshold (crucial) electron density $n_{e(cr)}$ is shown to exist. At such density the attraction of electrons and nuclei exceeds the kinetic pressure of degenerate electron Fermi gas. The minimum of crucial density corresponds to the nuclei with maximal charge Z (the higher the charge of a nucleus, the lower the threshold of the external compression). If such density is reached, a self-organizing process of "electron downfall to the nucleus" starts. This process is exoenergic and leads to the fall of electrons to the nucleus, Coulomb collapse of the electron-nucleus system, and formation of a supercompressed electron-nuclear cluster with the release of large amount of binding energy.

It is shown that the maximum binding energy shifts during such self-organizing collapse of the electron-nuclear system from $A \approx 60$ (for uncompressed "usual" electron-nuclear substance) to the area of high mass numbers $A > 200\text{-}2000$ and could render the synthesis of superheavy nuclei to be energy-efficient. The synthesis proceeds through the absorption of other nuclei by the collapsed nucleus. It is theoretically proved that the synthesis efficiency is ensured by both the width reduction and increased transparency of the Coulomb barrier in the extremely compressed electron-nuclear system. The release of binding energy through the absorption of nuclei by the electron-nuclear collapsed clusters may result in the simultaneous emission of lighter nuclei.

Also discussed in this report is the problem of satisfying the threshold requirements and achieving the crucial electron density $n_{e(cr)}$ in the experiments carried out. It has been shown that the threshold electronic density $n_{e(cr)}(R_{cr})$ is achieved during the accelerated motion of a thin spherical electronic layer (spherical wave of electrons), which goes to the center of a condensed target. In the volume of this accelerated layer, the processes of complete ionization of target atoms and pinch of electronic density up to the state of degenerate relativistic electronic gas take place. Threshold density of electrons in the volume of spherical accelerated layer (necessary for the beginning of the process of electrons and nuclei self-compression and for fast nuclear transmutation) is achieved on the particular radius $R<<R_0$ of the spherical layer, which depends on charges of target nuclei and initial density $n_e(R_0)$ of a spherical electronic layer near the external surface of the target R_0.

After the self-focussing moving spherical layer passes through a concrete part $R< R_{cr}$ of the target volume, the processes of restitution to a "normal" state of substance and cooling of products of nuclear reactions in this part take place. Near the center of a target ($R\to0$), there is a collision of a focusing spherical wave, additional increasing of electronic density, formation of a fixed spherical unmoving collapse and its retention by inertial forces. In this area the process of creation of most superheavy nuclei takes place. Such process of a "moving collapse" corresponds to serial processing of whole central part of a target.

It is assumed that this is the only mechanism that explains the synthesis of superheavy and other anomalous nuclei observed in the experiments carried out at the Electrodynamics Laboratory Proton-21.

The model of interrelation between beam-plasma and nuclear processes

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The problem of controlled transmutation of elements and isotopes belongs among one of the most promising scientific challenges. To date, the only working concept in the area of nuclear transmutations is the one of influencing nuclear system by using high-energy particle beams. On the whole, one can say that the controlled energy delivery to nuclear-scale targets is the basic one for solving the problems of transmutation of nuclei. As carriers, employed to deliver the energy to nuclear system, one of the most convenient are charged particle beams. The research into the effects of concentrated energy flows on condensed media, begun by the Authors since 1996, has been carried on at a number of facilities.

In the traditional approach, the high-energy charged particle beams are produced in accelerators, while the process of the beam-to-nuclei energy transmission occurs as a result of paired collisions of high-energy particles with the nucleus. The employment of the technology of paired collisions with nuclei is based on the visualization that individual processes are the most vital in nuclear transmutations.

The Authors conceived a clear-cut picture, bringing it to maturity, of a possibility to generate non-linear waves with the aid of high energy localization in the condensed media, using concentrated energy flows that would move from periphery to center, thereby causing creation of extreme states of the condensed matter as a result of collapse of this wave.

The main underlying idea of this approach was transmission of energy to nuclear system as a result of the collective processes. Than, the scenario of process can be described in the following way:

- The action of electron flows causes, as the incident power increases, a high-pressure pulse to appear on the surface.
- The high-power pressure pulse generates a non-linear acoustic wave, bringing about a temperature rise in electron and ion sub-systems of the condensed medium. Note that for a high-power REB the yield strength of target material is exceeded very rapidly, and the medium begins to behave as viscid-elastic one.
- Emergence of the single-fluid plasma hydrodynamic floating matter regime. As the power impact increases, the ionization equilibrium moves fast into the total matter ionization region.
- As an additional charge is introduced by e-beam into target material, there comes such a moment of time after which the additional e-beam charge has not enough time to leave the beam relaxation region due to the diffusion mechanisms in the target medium. From that time on, such self-consistent electromagnetic fields emerge in the condensed medium that exceed the

level of field fluctuations in the target and two-fluid electron-ion hydrodynamic floating regime. The appearing floating matter regime is visualized as propagation of such non-linear electron wave following the ion stream that, at large electron flows, spins round rapidly and falls back onto itself.

- In the collapse region, which is near the surface target for short high-power electric current pulses, there appear large local electron densities and electric fields. An additional heating of the medium occurs. A target region comes into being with extreme parameters that is viewed as single-component plasma, consisting of electrons and nuclei of target matter.
- The interaction of the flows of nuclei and electrons in the dense target plasma under a large electric field of the electron wave brings about the appearance of plasma-field structures with small spatial scales and large fields (nearing the nuclear fields).
- The value of the emerging field allows for variations of the initial and boundary conditions in the nuclear dynamics equations.
- These variations bring about a modification of the coupling energy in the nuclei and a modification of nuclear structures. In other words, collective nuclear structures come into being in which the Coulomb barriers of nuclei are collectivized.
- Nuclear matter with electromagnetic field structure emerges.