ISOTOPIC COMPOSITION PECULIARITIES IN PRODUCTS OF NUCLEOSYNTHESIS IN EXTREMELY DENSE MATTER

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Presented are the results of experimental study on synthesis of wide range of isotopes in a cold superdense monoelemental plasma. Initial conditions necessary for plasma bunch formation were provided by specially organized coherent impact on a solid target with a total energy up to 1 kJ. More than 3500 shots were performed with various targets made of light, medium and heavy elements. Products of nucleosynthesis in the target precipitated on the inner surface of a concentrator surrounded the target and on an attached accumulating screen. Subsequent analysis of the products reveals presence of a wide range of elements. Elements with nuclei three and more times heavier than the nucleus of the initial element are detected in the products. The isotopic compositions of the produced elements differ from spot to spot and significantly differ from the natural one. In the products generated in the heavy element targets presence of unknown superheavy elements is detected with several different spectroscopic methods.

Introduction

This work is the first publication of the experimental results of investigations on nuclear transmutations in the super compressed substance.

The results were gained in the Electrodynamics Laboratory 'Proton–21' (Ukraine, Kiev) in 1999–2002. The laboratory was established within the scope of a venture project on creation of a technology for the radioactive waste utilization.

The project was based on the idea of transmutation of the radioactive isotopes into the stable ones due to concentrating the superdense power in the condensed matter. A few experimental installations have been built in the laboratory. The first successful experiment that manifested a specific damage in the target was performed on February 24, 2000. Since then, more than 3500 'shots' (dynamic compressions of solid targets) were performed.

1. Multinuclear reactions in superdence substance

1.1. *Experiment*

The main experimental setup realizes the consecutive space–time energy compression and is capable to impact up to 1 kJ of energy during the pulse time less than 100 ns. The electron beam is employed as an intermediate energy compressor. At the last stage, the energy is compressing in the solid concentrator surrounding the solid micro target. The specific dimension of the concentrator is about one millimeter.

The target evaporates as a result of dynamic compression ('shot'). Products precipitate on the internal walls of the concentrator and on the special accumulating screen. The precipitated products have the form of irregularly scattered drops, beads, films, etc.

1.2. *Analysis*

Precipitated products were analyzed to determine their isotopic and elemental compositions. The analytical methods employed were:

EPMA — electron probe microanalysis;
AES — Auger–electron spectroscopy;
SIMS — secondary ion mass spectrometry;
LMS — laser mass spectrometry;
RBS — Rutherford back scattering of accelerated alpha–particles.

As a rule, each sample was analyzed in some different spots. Some regions (spots) were also analyzed by different methods. Summary of the samples and probes analyses is listed in Table 1.

In addition to the measurement of isotopic and elemental composition of products precipitated on the surfaces of the concentrator and screen, the distribution of elements in depth of the accumulating screen was measured. Altogether 13143 analyses of different samples and different sample spots were performed and registered in databases.

1.3. *Main results of elemental and isotopic composition analysis*

Analyses show that the products contain a wide spectrum of the light, medium and heavy chemical elements absent in the initial materials involved in the process of nuclear transformation.

Table 1. List of analytical methods and number of analyses.

Method	num. samples	num. of probes
EPMA	607	8936
LMS	20	297
AES	21	1303
SIMS	20	399
RBS	40	40
EPMA+LMS	38	1227
EPMA+AES	39	1260
EPMA+SIMS	19	487
EPMA+LMS+AES	4	164
EPMA+LMS+SIMS	2	57
EPMA+AES+SIMS	6	260
EPMA+LMS+AES+SIMS	1	43
LMS+AES	1	29
AES+SIMS	2	28
total EPMA	716	10845
total LMS	66	1001
total AES	74	1118
total SIMS	50	527
total RBS	40	40
TOTAL	946	13531

This fact is illustrated in Fig. 1. In the figure, the elemental composition of contamination of the target material (chemically pure copper) and the abundances of detected elements in the products deposited on the accumulating screen are presented.

The initial composition (a) was measured with the most sensitive apparatus — a mass spectrometer of glow discharge VG 9000 (VG Elemental, UK), sensitivity from 100 % to ppt level in a single analysis. Elemental compositions of the products in the same screen after one shot were measured with three different apparatus: (b) EPMA analyzer REMMA–102 (Ukraine), analyzed were 417 beads and 113 spots of 0.3 mkm diameter; (c) SIMS analyzer IMS 4f (CAMECA, France), 5 squares 250 mkm on side and depth of 0.1 mkm; (d) Auger spectroscope JAMP–10S (JEOL, Japan) 24 spots of 5. . . 25 Å depth.

As it can be seen from Fig. 1, both the light elements (with the mass

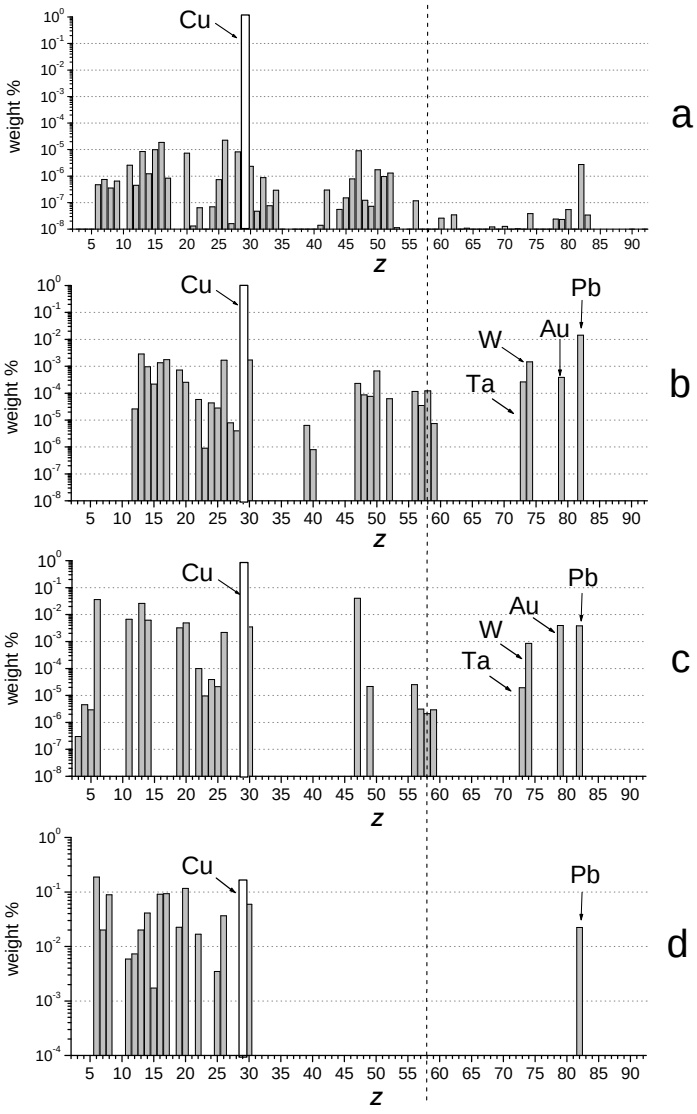

Figure 1. Elemental composition. (a) initial target material, (b), (c), (d) — products deposited on accumulating screen.

number less than the initial copper) and the heavy ones are present in the products in quantities by a few orders of magnitude exceeding contamination in the initial material. It should be emphasized that the elements with atomic masses exceeding two masses of initial element (elements to the right of vertical dashed line on Fig. 1) were detected in considerable amounts.

From the above described measurements, the total number of atoms other than copper was estimated. These data are listed in Table 2.

As it can be seen from Table 2, the total number of generated atoms in a shot was 1.6×10^{18}, by four order of magnitude more than that of initial contamination.

The same estimation was derived from the 'marked target' experiments. The target for these experiments were fabricated from radioactive cobalt (^{60}Co). After a 'shot', the system activity (number of radioactive decays per second) decreased by the amount equal to transmutation of ^{60}Co 10^{18} atoms into non–active elements — intensity of the ^{60}Co spectral lines decreased while no line of other radioactive isotope appeared.

For clarification of the nucleosynthesis process, the isotopic composition of the products was analyzed. An incentive reason for this was the well–known fact that isotopic composition of any element is almost identical throughout the Solar system as determined by its evolution.[a] Only some meteorites formed at an early stage of the solar system evolution show a different isotopic composition (see, e.g. [1,2]).

Analyses of the isotopic composition were done with two different methods, i.e., LMS and SIMS (see Table 1). As it was found out, most of the analyzed spots of an accumulating screen had isotopic composition varying from spot to spot.

Examples of the isotopic composition of some elements are presented in Fig. 2.

As it can be seen from this figure, the isotopic composition of the elements produced from the copper target, differs significantly from the natural composition.

Consequently, both the elemental and isotopic composition indicates on an artificial origin of the detected nuclei.

[a]It is not valid for the isotopes of lead and some other elements being the final (stable) isotopes of a nuclear decay chain.

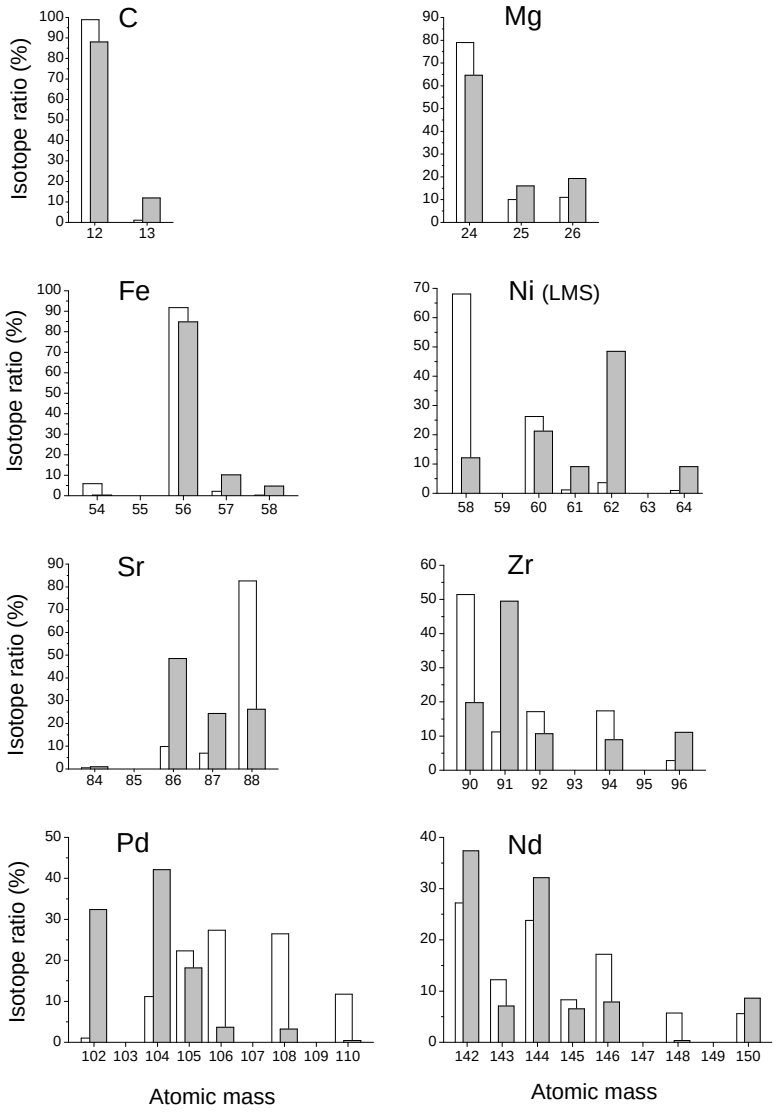

Figure 2. Isotopic composition of some elements measured with LMS (indicated) and SIMS (others). Natural composition is depicted with empty bars, after–shot one — hatched bars.

Table 2. Number of atoms in the surface layer of accumulating screen.

Element	Z	Init Cu target	Accum. screen
Li	3	5.1 E+10	3.8 E+12
Be	4	3.2 E+10	4.1 E+13
B	5	1.2 E+11	2.2 E+13
C	6	4.1 E+12	2.6 E+17
N	7	3.3 E+09	8.7 E+11
O	8	1.3 E+09	3.3 E+12
Na	11	3.2 E+12	2.4 E+16
Mg	12	9.1 E+11	3.2 E+15
Al	13	2.2 E+13	3.8 E+17
Si	14	2.5 E+12	1.2 E+17
P	15	1.4 E+13	2.0 E+16
S	16	2.5 E+13	1.2 E+17
Cl	17	1.5 E+09	1.4 E+17
K	19	—	6.0 E+16
Ca	20	4.9 E+12	2.9 E+16
Ti	22	8.7 E+10	3.9 E+15
V	23	7.9 E+09	6.6 E+13
Cr	24	1.3 E+11	2.5 E+15
Mn	25	1.2 E+12	1.6 E+15
Fe	26	3.9 E+13	9.1 E+16
Co	27	2.8 E+10	3.9 E+14
Ni	28	1.5 E+13	2.0 E+14
Zn	30	2.7 E+12	8.0 E+16
Y	39	8.9 E+08	2.0 E+14
Zr	40	2.5 E+09	2.8 E+13
Ag	47	5.6 E+12	3.7 E+16
Cd	48	5.7 E+10	2.2 E+15
In	49	2.8 E+10	1.9 E+15
Sn	50	5.1 E+11	1.6 E+16
Te	52	3.4 E+11	1.4 E+15
Ba	56	1.5 E+10	2.4 E+15
La	57	5.5 E+08	7.2 E+14
Ce	58	8.2 E+08	2.5 E+15
Pr	59	1.1 E+09	1.5 E+14
Ta	73	4.0 E+08	4.2 E+15
W	74	1.5 E+10	2.3 E+16
Au	79	8.0 E+09	7.3 E+15
Pb	82	5.0 E+11	2.0 E+17
TOTAL		1.4 E+14	1.6 E+18

2. Production of superheavy elements

Presence of heavy elements (tantalum, tungsten, gold, and lead) among the products of nucleosynthesis from the copper target encouraged us to carry out experiments with heavier targets. In fact, since lead ($A(\mathrm{Pb}) = 207$) was produced from the copper target ($A(\mathrm{Cu}) = 63, 65$) then in similar way one should expect to get elements at the border of the periodic table and even beyond it if a target made from heavy elements is used.

These experiments with the platinum–bismuth targets were carried out. The results of analyses proved our expectations true: some spots on the accumulating screen revealed the presence of unidentified heavy elements just above the apparatus threshold of sensivity.

Then we returned to the copper target and used the same accumulating screen in multiple shots. This accumulating screen produced the lines of superheavy elements.

Typical mass spectra indicating on presence of the superheavy masses obtained with IMS 4f are presented in Fig. 3.

To identify the elemental composition of the accumulating screen surface, the Auger spectroscopy methods were used. The specific character of such analysis was caused by the problem of identification of the Auger peaks for the bulk set of the chemical elements present on the examined surface.

To identify the Auger peaks, the measurement was performed in a wide range of energies (30–3000 eV) to find out the ceiling Auger peaks in the range; the prolonged expositions (up to 3 hours) were also used to identify the low intensity peaks.

In the process of analysis, the unidentified peaks with the energies of 172, 527, 1096 eV, and a doublet 130 and 115 eV were registered. These peaks do not correspond to any of the catalogued peaks of chemical elements and can not be referred to any of the known artifacts.

Examples of the Auger spectra are presented in Fig. 4.

'Suspicious' samples were examined for presence of superheavy elements with the most direct method — Rutherford backscattering. Samples were irradiated with the beam of 27.6 MeV alpha–particles accelerated in U–120 cyclotron (minute details are presented in [3]). The energy spectrum of the scattered projectiles exhibited scattering centers corresponding to mass numbers in the range of 200–400 (a sample of spectra is presented in Fig. 5).

Thus, different methods of analysis detected the presence of unidentified

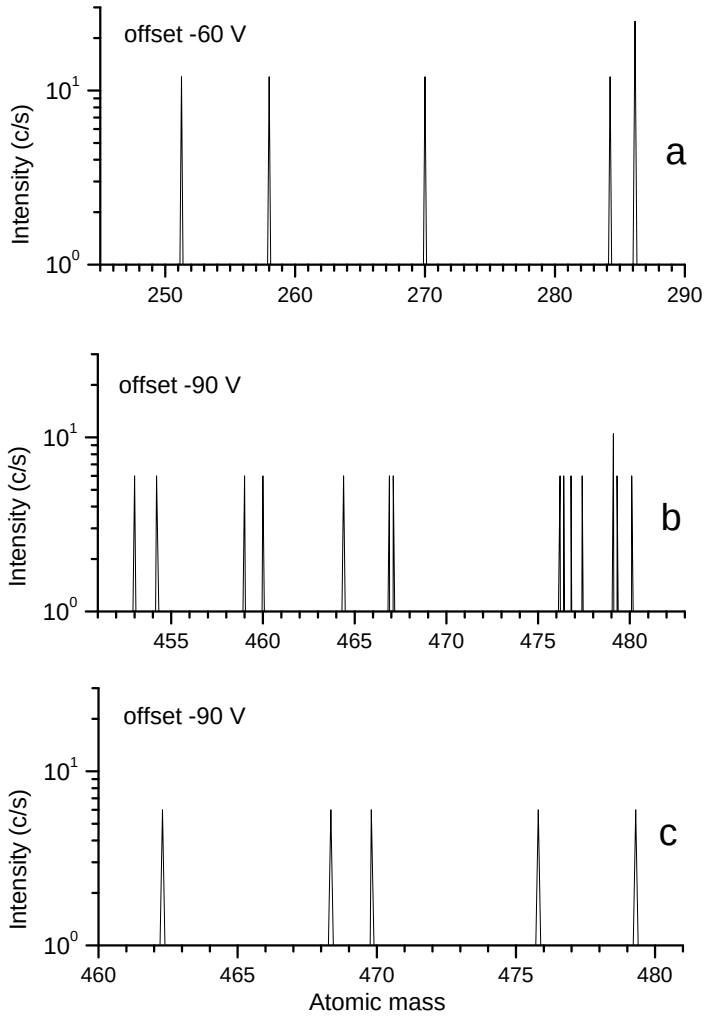

Figure 3. Mass spectra revealing presence of superheavy masses. (a) corresponds to a singe shot upon the platinum–bismuth target (copper screen), (b) 8 shots (copper targets, titanium screen), (c) 13 shots (copper targets, copper screen)

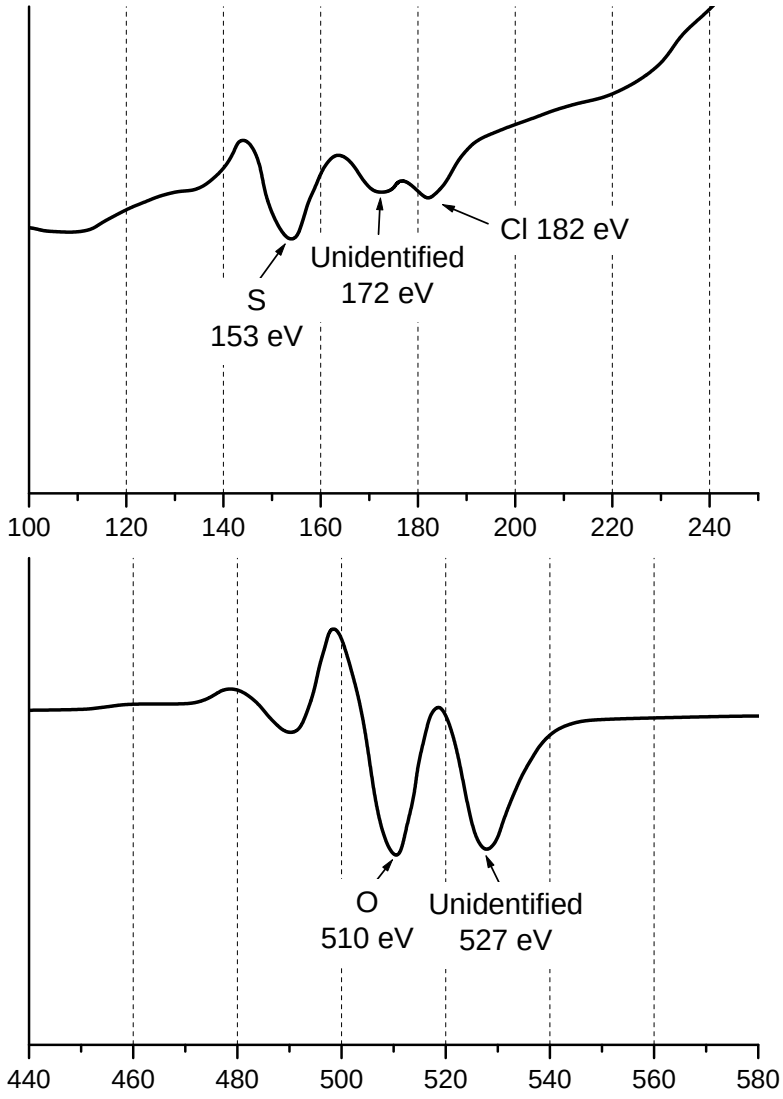

Figure 4. Sections of Auger spectra with unidentified peaks.

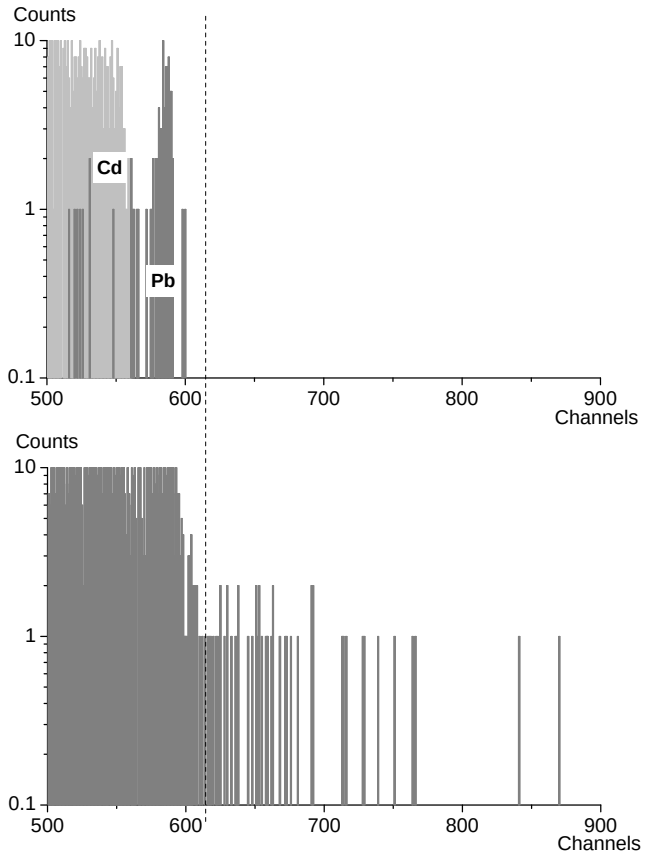

Figure 5. Raw Rutherford backscattering data, initial material (above) and after experiment (below).

superheavy elements among the products of nucleosynthesis in the heavy (lead, platinum, bithmus) targets.

3. Summary of results and discussion

Presented is the survey of experimental results of nucleosynthesis in the dynamically super compressed substance. The essence of results is as follows:

- In substance compressed up to superhigh density, the process of nucleosynthesis and transmutation occurs. This process takes place over macro volume of the target substance.
- Significant amount of synthesized nuclei requires more than two initial nuclei for their production.
- Radioactive isotopes were not observed in the products.
- The activity of the targets marked with radioactive isotopes was reduced after compression impact.
- The dynamic state of macro quantities of condensed substance was reached where the multiparticle reactions of synthesis took place.
- The products of nuclear transmutation reveal presence of quasistable superheavy nuclei.

The reactions in some sense are similar to the pycnonuclear reactions (the reactions in which nuclei tunnel through Coulomb barrier due to zero oscillations).

We are looking now for methods and technique for simultaneous measurement both the atomic and nuclear properties of superheavy atoms.

The results of our experiments allow us to suppose that the synthesized nuclei are the product of clasterization in the decaying superdense electron–nucleon plasma that corresponds to maximization of the binding energy per nucleon, dependent on the substance density, on the one hand, and on the neutron concentration in the certain volume of clasterization, on the other hand.

It is worth mentioning that our research in this field originated from a hypothesis that the nucleosynthesis should evolve in energetically efficient way due to inherent self–organizing properties of matter.

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