PROBABLE PRODUCTS OF LOW ENERGY NUCLEAR FUSION REACTIONS ON THE BODIES OF THE SOLAR SYSTEM

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– Abstract –
In the context of hypotheses about probable realization of low energy nuclear fusion reactions (LENR) there have been considered common features joining such seemingly alien to one another objects as meteorites, fulgurites and also the products of volcanic activity on Jupiter's satellite Io. Common for all of them is the combination of great values of pressure, temperature and electric current density. The most probable LENR for the Chelyabinsk meteor could be the reaction between magnesium and silicon nuclei contained in olivine and pyroxene, which were found in the meteorite. As a result of lightning strike quartz sand turns into fulgurite in which one can find metallic spheroids of troilite, alpha iron and shreibersite. These minerals are more specific for extraterrestrial objects. It looks as if two SiO_2 molecules are turned into two atoms of sulfur and one atom of iron:

$$^{28}_{14}Si + {}^{28}_{14}Si \rightarrow {}^{56}_{28}Ni^* \rightarrow {}^{56}_{27}Co^* \rightarrow {}^{56}_{26}Fe\ ;\ {}^{16}_{8}O + {}^{16}_{8}O \rightarrow {}^{32}_{16}S$$

Fusion of two $^{28}_{14}Si$ nuclei occurs in three stages. Initially the radioactive isotope $^{56}_{28}Ni^*$ is generated (half-decay period is ≈ 6 days). It turns into a radioactive isotope $^{56}_{27}Co^*$ (half-decay period is ≈ 77 days), and finally the stable $^{56}_{26}Fe$ isotope is formed. Anomalous quantities of sulfur and iron on the Jupiter satellite Io also appear as the products of these two LENR. These products are formed from quartz under the action of huge pressure induced by tidal heating of Io coupled with electric current of five million amperes flowing between Io and Jupiter. Weighty proof of LENR realization should be mass-spectrometric confirmation of the relative $^{56}_{26}Fe$ content increase in fulgurite as compared with Earth rocks.

In the framework of the hypotheses set forth by the author in *Infinite Energy* 114,[1] all phenomena accompanying the blast of Chelyabinsk meteor were regarded as evidences of probable realization of natural low energy nuclear fusion reactions (LENR) between magnesium and silicon nuclei contained in olivine and pyroxene, which were found in the meteorite. The ultimate products of these reactions are stable isotopes of iron, nickel and chromium which corresponded to maximum on the well-known curve of the relationship between specific binding energy and mass number:

$$^{26}_{12}Mg + {}^{28}_{14}Si \rightarrow {}^{54}_{26}Fe + 18.544\ MeV \quad (1)$$

$$^{24}_{12}Mg + {}^{30}_{14}Si \rightarrow {}^{54}_{26}Fe + 17.886\ MeV \quad (2)$$

$$^{25}_{12}Mg + {}^{29}_{14}Si \rightarrow {}^{54}_{26}Fe + 21.164\ MeV \quad (3)$$

$$^{26}_{12}Mg + {}^{30}_{14}Si \rightarrow {}^{56}_{26}Fe + 19.957\ MeV \quad (4)$$

$$2\,^{29}_{14}Si \rightarrow {}^{58}_{28}Ni + 16.437\ MeV \quad (5)$$

$$^{28}_{14}Si + {}^{30}_{14}Si \rightarrow {}^{58}_{28}Ni + 14.301\ MeV \quad (6)$$

$$2\,^{30}_{14}Si \rightarrow {}^{60}_{28}Ni + 15.606\ MeV \quad (7)$$

$$2\,^{26}_{12}Mg \rightarrow {}^{52}_{24}Cr + 22.986\ MeV \quad (8)$$

Here the new reactions (3) and (6) were added using nucleus ground and isomeric state parameters.[2]

Iron, nickel and chromium were really found in the Chelyabinsk meteorite and the percentage of these elements increases in a fused crust as compared with its body, whereas the percentage of silicon and magnesium decreases. Here are the weight-average percentage values obtained by Lutoyev et al.:[3]

	Si	Mg	Fe	Ni	Cr
body	18.99	14.22	19.27	0.24	0.36
crust	17.03	14.17	21.73	0.60	0.39

In view of the well-known data about the abundance of Mg and Si isotopes on the Earth[2] (^{28}Si – 92.230%, ^{29}Si – 4.683%, ^{30}Si – 3.087%, ^{24}Mg – 78.99%, ^{25}Mg – 10.00%, ^{26}Mg – 11.01%) and in the context of assumption about an inessential difference of this abundance in meteorites the most likely (other things being equal) expected is reaction (1). A heightened percentage of the isotope $^{54}_{26}Fe$ as compared with Earth rocks (5.845%) should point to its realization. Therewith reactions (2) and (3) should also lead to formation of this isotope. Therefore the necessity of mass-spectrometric identification of iron isotopes in Chelyabinsk meteorite comes out to the forefront. Unfortunately, that identification has not been made anywhere, as far as I know.

There are less likely (in any event for Chelyabinsk meteorite) other groups of reactions on intermediate stages of which short-lived radioactive materials are formed resulting in a stable isotope at the end of the process. For example, LENR is possible between the most widespread isotopes of magnesium and silicon in which after several consecutive conversions the stable chromium isotope is obtained:

$$^{28}_{14}Si + {}^{24}_{12}Mg \rightarrow {}^{52}_{26}Fe^* + 12.905\ MeV$$
$$^{52}_{26}Fe^* + {}^{0}_{-1}e \rightarrow {}^{52}_{25}Mn^*\ (T_{1/2} = 8.275\ h) \quad (9)$$
$$^{52}_{25}Mn^* + {}^{0}_{-1}e \rightarrow {}^{52}_{24}Cr\ (T_{1/2} = 5.591\ days)$$

This reaction goes in three stages. Initially at fusion of $^{24}_{12}$Mg and $^{28}_{14}$Si nuclei the radioactive isotope $^{52}_{26}$Fe* is formed (half-decay period is ≈ 8 hours). It quickly turns by electron capture into a radioactive isotope $^{52}_{25}$Mn* (half-decay period is ≈ 6 days). An atom $^{52}_{25}$Mn*, in its turn, also executes an electron capture and turns into the most widespread stable chromium isotope $^{52}_{24}$Cr.

Another possible fusion reaction with a chain of transformations and resultant formation of iron can occur between equal silicon nuclei:

$$\begin{aligned} &^{28}_{14}\text{Si} + {}^{28}_{14}\text{Si} \rightarrow {}^{56}_{28}\text{Ni}^* + 10.917\ \text{MeV} \\ &^{56}_{28}\text{Ni}^* + {}^{0}_{-1}\text{e} \rightarrow {}^{56}_{27}\text{Co}^* \ (T_{1/2} = 6.075\ \text{days}) \\ &^{56}_{27}\text{Co}^* + {}^{0}_{-1}\text{e} \rightarrow {}^{56}_{26}\text{Fe} \ (T_{1/2} = 77.233\ \text{days}) \end{aligned} \qquad (10)$$

Fusion of two $^{28}_{14}$Si nuclei also occurs in three stages. Initially the radioactive isotope $^{56}_{28}$Ni* is generated (half-decay period is ≈ 6 days). It turns into a radioactive isotope $^{56}_{27}$Co* (half-decay period is ≈ 77 days), and finally the stable $^{56}_{26}$Fe isotope is formed.

By the way, this is just the reaction which has been observed on one star recently. The emission line of a radioactive isotope $^{56}_{27}$Co* with the energy of 847 keV in the transition reaction $^{56}_{28}$Ni* → $^{56}_{27}$Co* → $^{56}_{26}$Fe was reported at the burst of supernova SN 2014.[4] In this case, of course, nobody can suspect LENR, nevertheless, in some extreme terrestrial events it is not inconceivable that such reactions can obey a low-temperature scenario.

For the sake of the diversity pattern of such phenomena it is pertinent to note that sometimes LENR does not need any sort of extreme conditions at all. Such reactions reveal themselves even at room temperature and atmospheric pressure. So, in Vysotskii and Kornilova[5] they are observed in growing microbiological systems without any external force. Experimental results of mass-spectrometric identificatio[5,Fig.4.7] are evidence of clear reaction behavior:

$$^{23}_{11}\text{Na} + {}^{31}_{15}\text{P} \rightarrow {}^{54}_{26}\text{Fe} + 22.282\ \text{MeV} \qquad (11)$$

In the products of reaction (11) a mass spectrometer really recorded isotope ^{54}Fe and its concentration relative to isotope ^{56}Fe increased more than four times as compared with the natural value.

Alongside meteorites there are objects on Earth which deserve the most intent attention—fulgurites. It was noted that in parts of fulgurite's melt contacting with an unweathered rock the glass composition is characterized by a very high content of iron.[6] One can find even metallic spheroids of size up to 3 mm. They occur everywhere in fulgurites and are absent in surrounding rocks. The metallic particles under consideration consist of troilite, alpha iron and shreibersite; these rare iron-comprising minerals are more specific for extraterrestrial objects.[7] Mean values of specified phases are the following:

Troilite		Alpha iron		Shreibersite	
Fe,%	S,%	Fe,%	P,%	Fe,%	P,%
63.8	36.01	98.62	2.5	87.53	13.34

Of course, one can without any exotics treat the concentration increase of iron as a result of its chemical reduction and remelting. However, the action of powerful electric discharge during fulgurite formation gives grounds to suspect LENR participation. High pressures and temperatures developing at lightning passing through quartz sand can give rise to conversion of two silicon nuclei into an iron nucleus (Reaction 10). A more unusual assumption will be made below.

Released power has maximum value at the first stage of reaction when binding energy is released during a few milliseconds of lightning discharge. The explosive energy release does not occur at the second and third stages by reason of long half-decay period, *i.e.* the energy releases unnoticeably and gradually. Of course, one can notice it by gamma radiation at the moment of fulgurite formation and through several days after that; it goes without saying that nobody performed any dosimeter measurement. Therefore, it remains only to be satisfied with interpretation of aftereffects. The most significant of them should be the percentage increase of the isotope $^{56}_{26}$Fe as compared with Earth rocks. This is the most distributed natural iron isotope (its natural abundance is 91.754%), so that for proof of LENR realization it is necessary to confirm its concentration in fulgurite more than this value with the error not exceeding 1-2%. Thus, for the ultimate answer additional investigation of relative stable iron isotope content in mentioned mediums is needed.

Finally in this connection we should touch upon the supposition about the mechanism of volcanic activity on the most geologically active body of the Solar System—the utterly unique Jupiter satellite Io.[8] It is regarded that this activity is caused by tidal gravity interactions of Io with Jupiter, Europa and Ganymede.[9] During several billion years owing to these interactions the Io surface undergoes periodical deformations of about 100 m amplitude. Due to increasing huge pressures persistent interior heating occurs. Such heating causes and supports volcanism. As is known, more than 400 active volcanoes on Io erupt enormous masses of melted sulfur.[10] This sulfur is persistently poured out on the surface, forming vast lakes, and even rises up to a height of 300 - 500 km. Where does such quantity of sulfur come from if the satellite, as the majority of solid bodies of the Solar System, consists essentially of ultrabasic silicate rocks[11,12] surrounding the iron core[13] and seemingly, the relation of chemical elements in it should not differ from common ones?

In consideration of distinctive peculiarities leading to such anomalies together with huge tidal pressure one should also take into account the great undamped electric current on the order of $5{\cdot}10^6$A flowing between Io and Jupiter.[14] All these peculiarities permit expression of a cautious guess about participation of LENR in SiO_2 transformation. Two groups of processes can occur simultaneously. The first one is defined as the mentioned fusion of two silicon nuclei and conversion of them into iron nucleus (Reaction 10). The second process presents a fusion of two oxygen nuclei and their conversion into sulfur nucleus:

$$^{16}_{8}\text{O} + {}^{16}_{8}\text{O} \rightarrow {}^{32}_{16}\text{S} + 16.541\ \text{MeV} \qquad (12)$$

As a result of this LENR two SiO_2 molecules are converted into one iron atom and two sulfur atoms releasing overall excess energy of about 44 MeV. This guess is indirectly confirmed by the presence of considerable sulfur quantity in

troilite of fulgurites; that makes sense to regard troilite itself as a product of LENR reactions (10) and (12). Some part of oxygen, perhaps, does not participate in these processes and chemically combines with sulfur forming dioxide which is found in the atmosphere of the satellite and on its surface. Such approach makes it possible to give more plausible explanation for tidal heating of Io[9] and the existence of its iron- or iron-sulfide-rich core.[13]

Of course, there can be many assumptions and arguments pro or con on the subject of LENR possibility, however there are so many accumulated facts testifying to these reactions that they cannot be ignored any longer. Undoubtedly this subject deserves the most careful study. If such reactions really do take place, then in the not-so-distant future they have the prospect to be a background for development of new technologies of cheap and pure nuclear energy generation, for example, from talc or quartz sand without any radioactive wastes. End products of these reactions will be stable isotopes of iron, nickel and chromium so that a nuclear power plant in addition should be a metallurgical work producing pure isotopes of usual metals, which due its purity perhaps reveal new unusual properties.

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