The Trapped Neutron Catalyzed Fusion Model and the E-CAT

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1. Introduction

There are many important words about learning in a sacred writings in China. We want to cite here the words about recognition of object;
"When the mind is not present, we look, but do not see. We listen, but do not hear; we eat, but don't taste our food." [Great Learning].

This words say importance of our mind to observe object in general but is also true in research of scientific relation with objects including the cold fusion phenomenon (CFP) where sometimes we commit mistakes as the sacred writing says "when there is something you desire, you cannot be correct."

We have discussed types of approaches to the CFP [Kozima 2006 (Appendix B)] where our relation to the established principles of science is clearly discriminated. If we insist our approach is theoretical, we have to describe explicitly the fundamental point of view in the theory in relation to the principles of science and then deduce logically our conclusion which will be compared with the experimental facts. In the case of the CFP, the most controversial problem is the Coulomb barrier between charged particles to approach together in the range of nuclear force about a few fm (femtometer = 10^{-15} m). The energy E necessary to make the two protons approach to 1 fm is about 1 MeV. This is the reason that the $d - d$ fusion reactions in solids at around room temperature are almost impossible where the thermal energy E_{th} of relevant particles are about E_{th} = (1/40) eV = 2.5 $\times 10^{-2}$ eV ($E \sim 10^{7}\ E_{th}$) and the penetration probability of the Coulomb barrier is inverse-exponentially proportional to the height of the barrier above the particle energy (i.e. the probabilities of tunneling for the reactions are too small to be observed). [Kozima 2006 (Sec. 3.4)].

To escape this difficulty in the CFP, we proposed a model (the TNCF model) where neutrons are assumed to exist in the CF materials (materials such as PdD_x, NiH_x, TiD_x, - - where observed the CFP) play catalytic roles to induce nuclear reactions resulting in excess energy, nuclear transmutation, neutron emission, - - - [Kozima 1994]. The model has been successfully applied to almost all experimental data sets obtained hitherto and the results have been published in papers (e.g. [Kozima 2014]) and books [Kozima 1998, 2006]. It should be noticed that our approach is not confined into the CFP obtained in the deuterium systems but applicable to that in the protium systems.

2. TNCF Model

As introduced in the previous section, we have developed phenomenological analyses of experimental data obtained in the field of CF research. The NiH systems observed by many researchers including Italians (S. Focardi, E.G. Campari, F. Piantelli et al.) have also been analyzed successfully [Kozima 1998, 2006, 2010].

The nuclear reactions in the model reliable to the E-Cat are written down as follow:

$^{6}_{3}\mathrm{Li} + n \rightarrow {}^{7}_{3}\mathrm{Li}^{*} \rightarrow {}^{4}_{2}\mathrm{He}\ (2.1\ \mathrm{MeV}) + {}^{3}_{1}\mathrm{H}\ (2.7\ \mathrm{MeV}) \quad (E_l = 4.8\ \mathrm{MeV}),$ (1)

$^{7}_{3}\mathrm{Li} + n \rightarrow {}^{8}_{3}\mathrm{Li}^{*} \rightarrow {}^{8}_{4}\mathrm{Be}^{*} + e^{-} + \underline{\nu}_{e} \quad (\text{Beta decay} \quad \tau = 838\ \mathrm{ms}),$ (2)

$^{8}_{4}\mathrm{Be}^{*} \rightarrow {}^{4}_{2}\mathrm{He}\ (91.84\ \mathrm{keV}) + {}^{4}_{2}\mathrm{He}\ (91.84\ \mathrm{keV})\ (\text{Fission}\ \tau = ?\ E_a = 91.84\ \mathrm{keV}),$ (3)

where $\underline{\nu}_{e}$ is an electron neutrino.

$^{58}_{28}\mathrm{Ni} + n \rightarrow {}^{59}_{28}\mathrm{Ni}^{*} \rightarrow {}^{59}_{27}\mathrm{Co} - e^{-}\ (\mathrm{EC} \quad \tau = 7.6 \times 10^{4}\ \mathrm{y}),$ (4)

$^{60}_{28}\mathrm{Ni} + n \rightarrow {}^{61}_{28}\mathrm{Ni}^{*} \rightarrow {}^{61}_{28}\mathrm{Ni} + \gamma.\ (E_g = 0.01 - 90\ \mathrm{keV}),$ (5)

$^{61}_{28}\mathrm{Ni} + n \rightarrow {}^{62}_{28}\mathrm{Ni}^{*} \rightarrow {}^{62}_{28}\mathrm{Ni} + \gamma.\ (E_g = \text{thermal}),$ (6)

$^{62}_{28}\mathrm{Ni} + n \rightarrow {}^{63}_{28}\mathrm{Ni}^{*} \rightarrow {}^{63}_{29}\mathrm{Cu} + e^{-} + \underline{\nu}_{e}\ (\text{Beta decay} \quad \tau = 100.1\ \mathrm{y}),$ (7)

$^{64}_{28}\mathrm{Ni} + n \rightarrow {}^{65}_{28}\mathrm{Ni}^{*} \rightarrow {}^{65}_{29}\mathrm{Cu} + e^{-} + \underline{\nu}_{e}\ (\text{Beta decay} \quad \tau = 2.5172\ \mathrm{h}).$ (8)

(In the above equations, the symbol E_l stands for the liberation energy, E_a for alpha energy and E_g for gamma energy, respectively.)

In terms of our knowledge on the nuclear reactions in the CFP, we will give a glance on the experimental data about the E-Cat in the next section while we have given a brief comment on it already [Kozima 2013].

3. E-CAT and other applications

The applications of the CFP have been considered hitherto by many entrepreneurs including J.A. Patterson and A. Rossi. Here we take up the E-Cat invented by A. Rossi as an application of the CFP observed in NiH-systems by many especially by Italian researchers. We have some publications about the E-Cat; Patent application document [Rossi 2014], a paper measuring excess heat and nuclear transmutation [Levi 2013, 2014], explanation of the nuclear transmutation [Cook 2015], and replication of excess heat measurement [Parkhomov 2015]. From these publications, we will take up the data on the nuclear transmutation given in the paper by Levi et al. [Levi 2014].

They observed changes of isotopic ratio of Li and Ni in their CF material; hydrogen loaded Ni powder with additives (including Li) at temperatures more than 800 °C up to 1400 °C. They measured drastic decrease of $^{7}_{3}\mathrm{Li}$ (from 93% to 7.9 or 42.5% depending on the measuring methods) and increase of $^{62}_{28}\mathrm{Ni}$ (from 3.6% to 98.7 or 99.3%) [Levi 2014]:

"*The Lithium content in the fuel is found to have the natural composition, i.e. ^{6}Li 7 %*

and ^{7}Li 93 %. However at the end of the run a depletion of ^{7}Li in the ash was revealed by both the SIMS and the ICP-MS methods. In the SIMS analysis the ^{7}Li content was only 7.9% and in the ICP-MS analysis it was 42.5 %. This result is remarkable since it shows that the burning process in E-Cat indeed changes the fuel at the nuclear level, i.e. nuclear reactions have taken place. It is notable, but maybe only a coincidence, that also in Astrophysics a ^{7}Li depletion is observed [see e.g. 17]." [Levi 2014]

"*Another remarkable change in the ash as compared to the unused fuel is the identified change in the isotope composition of Ni. The unused fuel shows the natural isotope composition from both SIMS and ICP-MS, i.e. ^{58}Ni (68.1%), ^{60}Ni (26.2%), ^{61}Ni (1.1%), ^{62}Ni (3.6%), and ^{64}Ni (0.9%), whereas the ash composition from SIMS is: ^{58}Ni (0.8.%), ^{60}Ni (0.5%), ^{61}Ni (0%), ^{62}Ni (98.7%), ^{64}Ni (0%), and from ICP-MS: ^{58}Ni (0.8%), ^{60}Ni (0.3%), ^{61}Ni (0%), ^{62}Ni (99.3%), ^{64}Ni (0%). We note that the SIMS and ICP-MS give the same values within the estimated 3% error in the given percentages.*" [Levi 2014]

They did not observe neither electromagnetic radiation nor radioactive emission:

"*In summary, the performance of the E-Cat reactor is remarkable. We have a device giving heat energy compatible with nuclear transformations, but it operates at low energy and gives neither nuclear radioactive waste nor emits radiation. From basic general knowledge in nuclear physics this should not be possible. Nevertheless we have to relate to the fact that the experimental results from our test show heat production beyond chemical burning, and that the E-Cat fuel undergoes nuclear transformations. It is certainly most unsatisfying that these results so far have no convincing theoretical explanation, but the experimental results cannot be dismissed or ignored just because of lack of theoretical understanding. Moreover, the E-Cat results are too conspicuous not to be followed up in detail. In addition, if proven sustainable in further tests the E-Cat invention has a large potential to become an important energy source. Further investigations are required to guide the interpretational work, and one needs in particular as a first step detailed knowledge of all parameters affecting the E-Cat operation. Our work will continue in that direction.*"[Levi 2014]

The data obtained by Levi et al. [Levi 2014] are somewhat different from the data obtained by Focardi group for more than 10 years (e.g. [Campari 2000]) in several points. There are no radioactive emissions in this case in contrast to the former data [Campari 2000] and drastic changes of isotopic ratios of Ni even if the experimental conditions have been very different; temperature of the sample is very high in Levi et al. up to 1400 ^{0}C. And there are additives including Li (active elements noticed very often in other experiments also) in the case of Levi et al. We have to keep our watch on the further data in the E-Cat device in conjunction with other data in Ni-H systems to conclude the

science of nuclear reactions in the CF materials in these systems.

It should be mentioned that the positive effect of Li on the CFP had been noticed in the very early experiments already as I have noticed it in an article published in the TNCF News No. 91 [Kozima 2015]. McKubre et al. noticed an active effect of Li and expressed it as "Analyses of used cathodes have revealed the presence of several light elements in the near-surface region (to a depth of several microns); in particular, lithium."

4. Conclusion

The data obtained by Levi et al. [Levi 2014] are very interesting ones and seem indicating new features of the CFP in CF materials at higher temperature up to 1400°C. As we have noticed already that nuclear reactions in the CFP occur more easily in higher temperatures as several experiences had shown [Kozima 2014 (Appendix A4)]. The data obtained in the E-Cat apparatus might be showing a new phase of the science of the CFP, phenomenon including nuclear reactions in room temperature solids with no additive acceleration mechanism.

It is desirable to investigate other nuclear transmutations than $^{7}_{3}$Li and Ni because the data showing the isotopic changes of $^{7}_{3}$Li and $^{A}_{28}$Ni suggest existence of other nuclear reactions resulting in products of other nuclides, e.g. $^{3}_{1}$H, $^{4}_{2}$He, $^{59}_{27}$Co and $^{63}_{29}$Cu suggested by Eqs. (1), (1) (and (3)), (4) and (7) (and (8)), respectively.

This development of the application of a science reminds us the historical relation of science and technology revealed on the case of steam engine in 18th century [Kozima 1998 (Sections 12.19 and 14.1)] in contrast to the relation popular in 20th century.

"Technology go first usually then science follows it as history shows by a typical example of the steam engine: the invention of the modern condensing steam engine patented in 1769 by J. Watt preceded the establishment of the Second Law of Thermodynamics more than 80 years, which has given a solid basis for investigation of any engines sparing time and energy of mankind." [Kozima 1998 (Sec. 12.19)]

The development in the application of the CFP might be another example of this type very different from those cases of atomic energy, IT industry and genetic engineering in 20th century.

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[Great Learning] "9. The cultivation of the person lies in the correction of the mind." When you are angry, you cannot be correct. When you are frightened, you cannot be correct; when there is something you desire, you cannot be correct; when there is something you are anxious about, you cannot be correct. When the mind is not present, we look, but do not see. We listen, but do not hear; we eat, but don't taste our food. This is the meaning of "the cultivation of the person lies in the correction of the mind." (***The Great Learning***, Translated by A. Charles Muller);
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