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Analysis of cold fusion experiments generating excess heat, tritium and helium

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Abstract

The experimental data of the cold fusion phenomena, including the first data of Fleischmann et al. in 1989 which disclosed the existence of nuclear reactions in the solid at room temperature, were investigated with the trapped neutron catalyzed fusion model. The surprisingly large excess heat and comparatively small amount of tritium and few neutrons measured in the first experiment and the subtle observation of ^{4}He made later have been explained consistently by nuclear reactions in a Pd cathode surrounded by a surface layer of Li metal and/or PdLi$_x$ alloy. The density of the assumed neutron in the model was determined numerically from the experimental data.

The possibility of an explosive event as reported in the first paper was recognized as having a very small probability.

Keywords: Cold fusion; Excess heat; Nuclear reaction; Tritium; Helium; Neutron

1. Introduction

Since the first report of cold fusion by Fleischmann et al. [1] in 1989, supplemented by data on the detection of helium [2] in 1990, there have been several hundreds of experimental papers showing the generation of excess heat, helium 4 (^{4}He), tritium, neutrons, gamma rays and nuclear transmutation in various crystals containing hydrogen isotopes.

Five international conferences have been held and more regional or national conferences on this theme in these seven years. The proceedings of these conferences are sources of experimental facts, along with papers published in several journals open to this new branch of science. In addition to the data mentioned above, we will consider in this paper data [3,4] for excess heat and helium measured simultaneously in a similar system.

Among the experimental results on the cold fusion phenomenon, there is much excellent data showing a correlation between excess energy and helium produced in the experiments. From such data, we will consider here data providing a quantitative correlation between them [3,4]. The palladium cathode produced ^{4}He atoms at a rate of 10^{11} to 10^{12} atoms per second per watt of excess power.

These numerical data can be analyzed using the trapped neutron catalyzed fusion (TNCF) model proposed previously by us [5]. In the model, the fundamental assumption of the existence of stable trapped neutrons in the cold fusion material was made. To justify the assumption, the interaction of a neutron and lattice nuclei was analyzed and a new concept ‘the neutron affinity of a nucleus’ was proposed, having good correlation with materials where the cold fusion phenomenon occurred [6].

Using the model, a qualitative interpretation has been given successfully for various experimental data obtained in the cold fusion research hitherto. The model was applied to explain experimental data of excess heat and nuclear transmutation [7–10], excess heat and ^{4}He [11–14], excess heat in Pd|LiOH + H_2O [15,16], excess heat in Pd|LiOD + D_2O [17,18] and tritium and neutrons in Pd|LiOD + D_2O [19,20] systems.

We have analyzed some simple experimental data quantitatively and obtained results having good consistency. The data [8] showing an isotope shift of Sr in an experiment with Rb electrolyte in H_2O and an Ni cathode were explained numerically within a factor of three and as a density of the trapped neutron in the Ni cathode [7] obtained as $2 \times 10^7\,\mathrm{cm}^{-3}$. The data [14] showing generation of a huge excess energy and a large amount of helium, as high as 10^{20} to $10^{21}\,\mathrm{cm}^{-3}$, in Pd-black used as the cathode was analyzed with the model, and the density of the trapped neutron in the cathode obtained as approximately $10^{12}\,\mathrm{cm}^{-3}$ [13].

The results of this analysis show the validity of the

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basic assumption of the TNCF model to explain cold fusion phenomena.

In this paper, we present the results of an analysis of the first cold fusion experiment [1,2] and experiments showing correlation between the excess heat and helium produced in the experiment [3,4] in electrolytic systems.

The experiments by Morrey et al. [2] failed to detect helium in the Pd cathodes supplied by Fleischmann et al. On the contrary, the data by Miles and coworkers [3,4] showed clearly the quantitative correlation between the excess heat and helium in the gas of their closed system. This was not attempted in the first experiment [1], which used an open system. These experiments showed that the phenomenon generating the excess heat and nuclear products was occurring near the surface region of the massive cathodes used in the electrolysis. The analysis given in this paper will give a consistent interpretation of the phenomenon.

2. The TNCF model

We have developed a model [5,6] based on the existence of stable thermal neutrons in crystals. The neutron with thermal energy in a crystal behaves as a wave interacting with nuclei of the crystal lattice. The state of the thermal neutron in a crystal is a Bloch wave with a band structure in the energy spectrum.

On the same energy scale, two band systems are envisioned in the one-dimensional Kronig–Penny model: (1) one for the crystal and (2) one for the surrounding crystal so that there is an overlap of a band and a forbidden gap. Assumed parameters and obtained energies of the lowest band bottom were as follows [6]. (i) Lattice constants (1) $a = \sqrt{2} \times 10^{-8}$ and (2) 10^{-8} cm; (ii) energies of the lowest band bottom (1) 0.01 and (2) 0.02 eV.

Thus, the neutron in the crystal with the lowest energy cannot enter into the surrounding crystal where the energy corresponds to the forbidden gap.

Besides the band structure of a neutron Bloch wave, the interaction results in stability of the neutron against beta decay and also against capture by a nucleus if the neutron affinity [6] of the crystal is positive and large. There are several experimental results showing neutron trapping by crystals [21,22].

If a stable neutron trapped in a crystal suffers a strong perturbation induced by the effect of the disorder of the crystal potential, the neutron becomes unstable enough to be captured (or reacted with) by the nucleus, causing the perturbation. As a result of the capture (or reaction), nuclear products appear and excess energy is produced as shown by direct experimental results [23–27].

In the electrolytic system showing the cold fusion phenomenon, this situation will appear where the distribution of deuterons in the cathode metal becomes inhomogeneous or where ^{6}Li (^{87}Rb) atoms are distributed randomly on the surface layer of Li (Rb) metal on the Pd (Ni) cathode.

In the system with a Pd cathode and LiOD + D_2O electrolyte solution, the most realizable reaction is that between the thermal neutron and ^{6}Li with a large cross-section of approximately 1×10^3 barn [28]:

$$n + {}^6\text{Li} = {}^4\text{He}(2.1\,\text{MeV}) + t(2.7\,\text{MeV}) \qquad (1)$$

The triton with 2.7 MeV generated in this reaction (1) can pass through the crystal along the channeling axis on which there is an array of occluded deuterons or it can follow a finite path with a length determined by the interaction with the charged particles in the crystal. In these processes, the triton can fuse with a deuteron with a cross-section around 1.4×10^{-1} barn [29]:

$$t(2.7\,\text{MeV}) + d = {}^4\text{He}(3.5\,\text{MeV}) + n(14.1\,\text{MeV}) \qquad (2)$$

In the crystal, the neutron with 14.1 MeV generated in this reaction (2) can interact elastically with particles, especially with deuterons, giving a large amount of energy to the deuteron or inelastically dissociating it or fusing with it:

$$n + d = n' + d' \qquad (3)$$

$$n + d = n' + p + n'' \qquad (4)$$

$$n + d = t + \gamma + 6.25\,\text{MeV} \qquad (5)$$

$$n + {}^7\text{Li} = {}^8\text{Be} = 2{}^4\text{He} + e^- + \bar{\nu}_e + 16.2\,\text{MeV} \qquad (6)$$

The deuteron having an energy up to 12.5 MeV accelerated elastically by the neutron can fuse with another deuteron in two modes with a fairly large cross-section of the order of 0.1 barn [29]:

$$d + d = t(1.01\text{ MeV}) + p(3.02\text{ MeV}) \qquad (7)$$

$$= {}^3\text{He}(0.82\text{ MeV}) + n(2.45\text{ MeV}) \qquad (8)$$

Depending on the situation in the cold fusion system, the trapped thermal neutron can induce such trigger reactions as reaction (1) and the generated energetic particles could then sustain breeding chain reactions (2) to (4), (7) and (8), producing a lot of the excess heat and nuclear products.

Then, we can formulate our problem in the scheme of the TNCF model as follows.

The relation we have to use first in the analysis is the reaction (1) given in the preceding section. The reaction (1) is induced by a thermal neutron trapped in the sample (and thermal neutrons from outside) with a cross-section of around 10^3 barn and a release reaction energy $Q_1 =$ 4.8 MeV at the outer surface of the cathode where PdLi alloy and Li metal layers are formed by electrolysis.

In this reaction, neither a high energy neutron nor a gamma is generated, in agreement with the well-known fact that there were negligible neutron and gamma emissions compared with the thermal effects.

The neutron generated in reaction (2) interacts with deuterons in the sample and solution and Pd nuclei in the sample. The high energy neutron makes mainly elastic collisions, losing its energy to become a thermal neutron. A deuteron accelerated by the elastic collision with a high energy neutron can make inelastic or fusion reactions with another deuteron or a nucleus in the cathode, generating energy and particles. Neutrons generated in this process can become thermal neutrons, losing their energy to maintain the fusion reaction (1).

In addition to the reactions (1) and (2) mentioned above, reaction (6) is pertinent to the present experiment. The cross-section of the first reaction in (6) is not so large (approximately 7×10^{-2} barn for a thermal neutron), but the abundance of ^{7}Li(92.5%) is higher than that of ^{6}Li (7.5%). If the cycle of reactions starting from reaction (1) to (8) is effective, the main source of ^{4}He will be reactions (1) and (2). Otherwise, reaction (6) will play an important role in the helium generation. In this paper, we will concentrate our attention on the cycle started from reaction (1).

3. Experimental result of Fleischmann et al. and its analysis

In the pioneering paper by Fleischmann et al. [1], the observations were too abundant to treat in a paper on cold fusion phenomena. We will therefore take up only some features of the phenomenon from them in this analysis. With a Pd rod cathode of dimensions 0.4 cm $\phi \times 10$ cm, the following quantities were measured: the excess heat of 1.75 W ($= 1.75\,\mathrm{J\,s^{-1}} = 1.1 \times 10^{13}\,\mathrm{MeV\,s^{-1}}$), tritium generation of $4 \times 10^{11}\,\mathrm{s^{-1}}$ and neutron generation of $4 \times 10^{4}\,\mathrm{s^{-1}}$ (perhaps all with the same current but not described explicitly) when the electrolyzing current density was $64\,\mathrm{mA\,cm^{-2}}$.

These data gave a large t/n ratio of around 10^7 in addition to the high excess energy compared with the amount of tritium and neutrons. If we assume the usual nuclear reactions to produce the excess energy (5 MeV per event), the ratio of the number of events (excess heat/tritium) becomes approximately 10.

A search for helium expected to exist in the Pd cathode was made in cooperation with several laboratories in the USA using samples prepared by Fleischmann et al., and the results were published about two years later [2]. The amount of helium atom in the Pd cathode which generated excess heat was higher than that in Pd not generating excess heat. Though the difference between samples with and without the excess heat had been apparent, the conclusion was ambiguous not only because of the small amount of helium atom detected but also the small but finite existence of He in the as-received sample.

In the case of a Pd cathode used in electrolysis with Li electrolyte, surface layers of Li metal and/or PdLi$_x$ alloy have precipitated upon the surface of the Pd cathode which have positive neutron affinities. This structure satisfies the condition to trap thermal neutrons described above. In the surface layer, the periodicity of the crystal lattice should be much disturbed and the neutron Bloch wave trapped in the cathode would suffer strong perturbation, thereby inducing fusion reaction (1) with ^{6}Li in the layer if any.

Using the experimental data on the generation rate of triton $N_t = 4 \times 10^{11}\,\mathrm{s^{-1}}$, we can estimate the density n_n of the trapped neutron in the cathode. Let us assume the thickness l_0 of the surface layer composed of Li metal taking 1 μm and use the following relation between N_t and n_n:

$$N_t = 0.35 n_n v_n \, \rho_{Li} l_0 S \sigma_{nLi} \tag{9}$$

where $0.35 n_n v_n$ is the flux density of the thermal neutron ($\mathrm{cm^{-2}\,s^{-1}}$), v_n is the thermal velocity of the trapped neutron, ρ_{Li} is the density of the ^{6}Li nucleus in the layer, S is the surface area of the cathode, and σ_{nLi} is the fusion cross-section of the thermal neutron and ^{6}Li nucleus; $\rho_{Li} = 3.5 \times 10^{21}\,\mathrm{cm^{-3}}$, $l_0 = 10^{-4}$ cm, $v_n = 2.7 \times 10^5\,\mathrm{cm\,s^{-1}}$ ($T = 300$ K), $\sigma_{nLi} = 1 \times 10^{-21}\,\mathrm{cm^2}$, $S = 12.8\,\mathrm{cm^2}$.

The relation (9) gives us the density of the thermal neutron in this Pd cathode in the experiment [1] (where the natural abundance of ^{6}Li in LiOD was assumed)

$$n_n = 9.7 \times 10^8\,\mathrm{cm^{-3}}$$

The amount of energy liberated in reaction (1) is 4.8 MeV. This value multiplied by the number of events generating tritium gives a value 1.9×10^{12} MeV, about one sixth of the excess power observed in the experiment. This means that there were about six times more reactions liberating energy (5 MeV per event). Candidates for these excess reactions other than reaction (2) induced by the nuclear products of reaction (1) will be reactions (5) to (8).

The observed value of the t/n ratio 10^7 can be explained as follows. By reaction (2), a high energy neutron is generated and observed outside the electrolysis system. Using the cross-section $\sigma_{td} \approx 1.4 \times 10^{-1}$ barn and taking the path length of the 2.2 MeV triton as approximately 1 μm and the density of deuterium near the surface layer as $6.8 \times 10^{22}\,\mathrm{cm^{-3}}$, we obtain a ratio 5.3×10^5 in accordance with the experimental value 10^7 within one order of magnitude.

The coincidence of the t/n ratio will be improved largely if we take into consideration the elongation of the path length by channeling of tritium in the crystal [30,31]. There is an array of deuterons on the axis of each channel through which a triton can pass without energy loss unless it fuses with one of the deuterons there.

The problem of helium generation [2] remains inconsistent with the excess heat. As we will show in the next section, the helium measured outside the cathode [3,4] was comparable in amount with the tritium analyzed in this section [1]. It is, therefore, reasonable to consider that the main part of the helium produced in reaction (1) in the experiment with a volume cathode of the Pd|LiOD + D_2O experiment [2] had gone out from the cathode. Therefore, the ambiguous result of this helium search could not be taken as a decisive negative factor against the reality of cold fusion in the Pd cathode [1].

The excess heat measured for different values of current density j changed depending on j; for instance 0.153 W for $j = 8\,\mathrm{mA\,cm^{-2}}$, 1.751 W for $64\,\mathrm{mA\,cm^{-2}}$ and 26.8 W for $512\,\mathrm{mA\,cm^{-2}}$ in the case of the sample with dimensions 0.4 cm $\phi \times 10$ cm. The amount of tritium generated by reaction (1), and accordingly the excess heat, depend on the thickness of the surface layer, on the density of the trapped neutrons and also on the density of deuterium, especially in the near surface region. There are correlations between these quantities: for instance, the thicker the surface layer of Li metal, the higher is the density of the trapped neutron. Therefore, the excess heat depends nonlinearly on the electrolyzing current density, in accordance with the experimental result. This feature of cold fusion in the electrolytic system was discussed in a previous paper [18] in relation to the semi-quantitative result obtained at SRI International.

As we have pointed out in previous papers [31,32], there is a possible chain reaction induced by a high energy neutron with 14.1 MeV generating gigantic excess energy and a large number of nuclear products in an optimum situation, especially in massive samples. Therefore, the occurrence of explosive heat generation as suggested in the paper [1] should not be denied simply and carelessly, though its probability is very small and its occurrence is stochastic in nature.

4. Experimental result of Miles and coworkers and its analysis

In the paper showing the correlation of excess heat and helium production, the experimental procedure was explained without ambiguity [3,4]. We can treat their result with confidence. Essential results pertinent with our analysis are summarized as follows. The palladium cathode in the shape of a rod had an area $S = 2.6\,\mathrm{cm^2}$ and produced ^{4}He of 10^{11} to 10^{12} atoms per second per watt of excess power. A similar analysis to that given in the previous section was applied to these data.

Contrary to the case of the double-structure cathode containing Pd-black inside [14], where the generated helium was piled up in the Pd-black particles, the helium was observed in the electrolysis gas in the above experiment. Therefore, we have to assume that the reaction generating observed helium occurred in the surface layer of the Pd cathode, where Li metal was precipitated by electrolysis.

Now, let us consider numerical relations between the reactions occurring in the system.

Let us define probabilities P_2 and P_2' of the occurrence of reaction (2) following reaction (1) in the sample and in solution respectively:

$$P_2 = \zeta \rho l \sigma_{\mathrm{td}} \tag{10}$$

$$P_2' = \zeta' \rho' l' \sigma_{\mathrm{td}} \tag{11}$$

where ζ and ζ' are the relative number ratios of tritons going inwards and outwards ($\zeta + \zeta' = 1$) respectively to the total generated tritons, ρ and ρ' are the densities of deuterium in the sample and in solution, l and l' are the path lengths of the triton in the sample and solution respectively, and σ_{td} is the fusion cross-section of reaction (2) at an energy range of the triton from 0.1 to 2.7 MeV.

For one event of reaction (1), reaction (2) occurs P_2 times in the sample and P_2' times in solution. Some of the neutrons generated in reaction (2) will induce several reactions and produce energy Q_3 and Q_3' as a whole in the sample and in solution respectively. The total energy generated by the successive reactions starting from the first reaction (1) is expressed as follows:

$$\varepsilon = Q_1 + P_2 Q_2 + Q_3 + P_2' Q_2 + Q_3' \tag{12}$$

In this equation, we can put values $Q_1 = 4.8$ MeV and $Q_2 = 17.6$ MeV respectively, assuming that all energy generated by reactions (1) and (2) is thermalized in the system.

The total excess energy generated in the sample during the time t, in which N events of the reaction (1) occurred, is given as

$$E = N\varepsilon \tag{13}$$

The number N_{h} of helium atoms created at the surface of the sample and in solution, observed in this experiment, is then given by

$$N_{\mathrm{h}} = N(1 + P_2 + P_2') \tag{14}$$

Let us estimate the number $\nu_1 \equiv N_{\mathrm{t}} = N/t$ of reaction (1) in unit time. Because we consider reaction (1) to be induced mainly by the trapped thermal neutron in the sample (neglecting the effect of the thermal neutron from outside), N_{t} is given by relation (9).

Then, the number ν_2' of reaction (2) in solution in unit time is given as follows:

$$\nu_2' = \nu_1 P_2' \tag{15}$$

Helium atoms observed in this experiment are those generated at the surface and in solution. Therefore, we have the following relations among the number N of reaction (1), the total excess energy E, the observed number of helium atoms N_{h}, and the time of the experiment t:

$$E = N\varepsilon \tag{16}$$

$$N_{\mathrm{h}} = (\nu_1 + \nu_2')t \tag{17}$$

Taking a path length of 2.7 MeV triton as $l' = 1\,\mu\mathrm{m}$ and $\rho = 6 \times 10^{22}\,\mathrm{cm^{-3}}$ for heavy water, we obtain $P_2' = 3.4 \times 10^{-6}$ with $\sigma_{\mathrm{td}} = 1$ barn. A similar value is obtained for P_2 in the cathode. This means 3.4×10^{-6} neutrons with

Table 1
Neutron density n_n and relations between the numbers N_x of event x obtained by theoretical analysis of experimental data on the TNCF model ($N_Q \equiv Q$ MeV/5 MeV)

Reference	System	Measured quantities	n_n/cm^{-3}	Other results
Fleischmann et al. [1]	Pd/D/Li	Q, t, n $N_t/N_n \approx 10^7$ $N_Q/N_n \approx 5.6 \times 10^7$	$\approx 10^9$	$N_t/N_n \approx 5.3 \times 10^5$ $N_Q/N_n \approx 8.6 \times 10^7$ $N_Q/N_t \approx 5.5$
Miles and coworkers [3,4]	Pd/D/Li	Q, ^{4}He ($N_Q/N_{He} = 1$ to 10)	10^9 to 10^{10}	$N_Q/N_{He} \approx 5$

14.1 MeV are generated in solution for one triton or for one thermal event generating an energy of 4.8 MeV. The smallness of this value of the probability gives an answer to the main puzzle of negligible neutron and gamma emission compared with the thermal effects:

$$N_h/N_n \approx 1 \times 10^7$$

where N_n is the number of events generating neutrons. Therefore, we may assume hereafter $P_2 = P'_2 = 3.4 \times 10^{-6}$ for simplicity, considering similarity in the sample and solution.

Then, the relations we can use with experimental data reduce as follows:

$$E = N_h \varepsilon \tag{18}$$

$$N_h = N = N_{tt} \tag{19}$$

Using experimental values $N_h/t = 10^{11}$ to $10^{12}\ \mathrm{s}^{-1}$ for $E/t = 1\ \mathrm{J\,s}^{-1}$, $S = 2.6\ \mathrm{cm}^2$, neutron thermal velocity $v_n = 2.7 \times 10^5\ \mathrm{cm\,s}^{-1}$, density of ^{6}Li $\rho_{Li} = 3.5 \times 10^{21}\ \mathrm{cm}^{-3}$ (for Li metal with natural abundance of ^{6}Li), $\sigma_{nLi} \approx 10^3$ barn, we obtain the following values:

$$n_n l_0 = 1.1 \times 10^5 \text{ to } 10^6\ \mathrm{cm}^{-2}$$

Assuming the thickness l_0 of the surface layer of Li metal to be 10^{-4} cm, we obtain the density of trapped neutrons in the Pd cathode as

$$n_n = 1.1 \times 10^9 \text{ to } 10^{10}\ \mathrm{cm}^{-3}$$

This value of the density n_n could be compared with the value $9.7 \times 10^8\ \mathrm{cm}^{-3}$ obtained in an analysis given in the previous section of a similar experiment, where excess heat and tritium were observed.

The similarity of amounts of excess heat in these two experiments should be noted; in the latter case [3] with a rod cathode it was approximately 1 W, similar to the value of 1.75 W in the former [1] with a wire cathode.

In the above calculation, we assumed constancy of the neutron density n_n in the sample. In reality, this is not valid; n_n varies and it causes N_t and the power generation N_h to fluctuate.

Using the values of E, n_n, Q_1, Q_2 and P_2 in the relation (13) and assuming $Q_3 \approx Q'_3$, we can calculate Q_3 as 26 MeV. This value gives us an estimation of the number of reactions the triton with 2.7 MeV induces. If we assume that one nuclear reaction generates about 5 MeV on average, the number of reactions induced by the triton is about five. This situation is very similar to the experimental data in the previous section, where the factor was six. These values are not absurd considering a model calculation given before [13].

Thus, the density of trapped thermal neutrons in the Pd cathode was determined as approximately $10^9\ \mathrm{cm}^{-3}$ in the first experiment [1] and 1.1×10^9 to $10^{10}\ \mathrm{cm}^{-3}$ in the later experiment [3,4], in good agreement with the first value determined in the different samples.

Numerical data obtained in Sections 3 and 4 are tabulated in Table 1.

5. Conclusion

Several typical experimental results obtained in electrolysis experiments including the pioneering work of Ref. [1] have been analyzed using the TNCF model, giving a consistent understanding of the physics in the cathode materials.

The pioneering paper [1] by Fleischmann et al. includes abundant results (excess heat, tritium, neutron and gamma) of a long experimental work, which could not be understood consistently until now. The analysis given in this paper will elucidate the value of the work clearly and substantiate the cold fusion phenomenon.

In the experimental result by Miles and coworkers [3,4], there is one ambiguity about the rate of ^{4}He production, 10^{10} to 10^{11} atoms per second. In our model of cold fusion, the reactions are essentially stochastic phenomena having only qualitative not quantitative reproducibility. Therefore, even in the experiments of Refs. [3,4], there should be a fluctuation in the production rate of helium of about one order of magnitude. One should not refuse to accept the result [3] for an ambiguity of this magnitude.

In a preceding paper [7] we have analyzed experimental data on heat and nuclear transmutation, and obtained a value of $10^7\ \mathrm{cm}^{-3}$ for the trapped neutron density in an Ni cathode with Rb electrolyte in H_2O. In another paper in which huge excess heat and a large amount of helium generation were analyzed [13], we obtained a density approximately $10^{12}\,cm^{-3}$ of trapped neutrons in the Pd-black cathode with Li electrolyte in D_2O. In the present analysis, we obtained a value approximately $10^9\,cm^{-3}$ in the Pd rod cathode with a diameter of 4 mm and 10^9 to $10^{10}\,cm^{-3}$ in the Pd rod cathode with a surface area of $2.6\,cm^2$ with Li electrolyte in D_2O.

These results show consistency in all experimental results obtained hitherto and support the TNCF model as a working model to analyze the cold fusion phenomenon. The only fundamental assumption made, on which the model is based, is the stable existence of the trapped neutrons in cold fusion materials. Supplementary assumptions were made about the thickness of the surface layer, the constancy of the density of the trapped neutrons, and the path length of the tritium with 2.7 MeV. The new concept 'neutron affinity of nuclei in lattice' introduced to justify the model and the success of the analysis verifies the existence of such neutron stability against beta decay and against fusion with one of lattice nuclei. The basis of the concept is the fact that a neutron in a nucleus (e.g. deuteron) is stable, interacting with a proton in it. This problem is not solved yet. However, as we saw above, the assumption of the trapped thermal neutron explains various experimental data consistently, which is some evidence of its reality.

The conclusion given above supports the reality of the experimental result obtained by Fleischmann et al. [1], first published in this journal in 1989, which has often been a target of controversy. The model tells us that it is possible that some events may occur with small probability where a huge excess energy is generated to melt the sample in an optimum situation formed by stochastic processes in the sample.

We hope further experiments will be carried out, taking into account the results of analyses by the TNCF model given in this paper.

In conclusion, relations between those physical quantities observed in cold fusion experiments have been explained consistently based on an assumption which has a probable basis in conventional physics. The cold fusion phenomenon has obtained solid support from conventional physics by the success of the analysis given above.

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