*Cold Fusion*, 17, 12 – 14 (1996), ISSN 1074-5610

# Excess Energy Data in a Pd/D System Examined

H. Kozima,
Shizuoka University,
Shizuoka, Japan

**Abstract**

One of the most elaborate experimental data in cold fusion experiments have shown a semi-quantitative relation between the excess energy $Q$, D/Pd ratio $x$ in the sample and electrolyzing current density $i$. The relation was investigated on the TNCF model and a qualitative explanation was given consistent with other experimental data in cold fusion.

## 1. Introduction

There are several excellent data in cold fusion experiments showing some numerical relations between quantities related with the phenomenon. In the case of the electrolysis experiment, the relations are between the electrolyzing current density $i$, the relative deuterium density $x$ in the sample, the amount of generated excess energy $Q$, helium, and tritium, the change in isotope ratio of elements in cathodes, and so on.

We have analyzed experimental data (a) on the change of Sr isotope ratio[1)] in Ni cathode with Rb electrolyte in $H_2O$, (b) on huge excess energy and a large amount of $^4$He in the cathode with Li electrolyte in $D_2O$[2)], and (c) a fine relation between excess energy and helium[3)] out of Pd cathode with Li electrolyte in $D_20$. My fundamental point of view was expressed in a previous paper[4)].

The results of the analyses gave me a consistent understanding of the cold fusion phenomenon in electrolysis experiments: The density of the trapped neutron in the sample, assumed in my model, is of the order of $10^7$ in the case of (a)[5)], $10^{15}$ in (b)[6)] and $10^{12}$ cm$^{-3}$ in (c)[7)]. Especially in the case of (a), a relation between the excess energy and the change of isotope ratio was reproduced exactly by a factor 3, even if the amount of Rb precipitation on the cathode was assumed to be the same. And also in the case of (c), we could determine the excess energy and the number of reactions induced by a trigger reaction as 26 MeV and about 5, respectively.

With the same model, we will analyze another excellent data[8] giving a relation between $Q$, $i$ and $x$ in $D_2O$ electrolysis with Pd cathode.

## 2. Experimental Results and Basis of Theoretical Explanation

Elaborate research works in SRI International[8] gave us an empirical relation between the excess energy $Q$, the electrolyzing current density $i$ and the average density of deuterium relative to Pd atom $x$ in the cathode:

$$Q = C(i - i_0)^a (x - x_0)^b |\delta x/\delta t| \qquad (1)$$

In this relation, $C$ is a constant depending on the temperature, material and etc., $i_0$ and $x_0$ are threshold values of $i$ and $x$, respectively, and $a$ and $b$ are indices determined by experiments; a ~ 1, $b$ ~ 2, $|\delta x/\delta t|$ is the speed of deuterium occlusion.

Notice that the variables in this relation are not independent each other, as Dr. M. McKubre explained in a discussion at a conference.

Looking at the graph showing a curve of the above relation and experimental points dispersed widely around the line, we understand that the equation expresses a rough relation between variables in it. So, we may treat the relation as a statistical one. The threshold values $i_0$ and $x_0$ are, also, should be taken as rough marks.

We will try to investigate the relation (1) in terms of the TNCF model.

In the light of the model, the cold fusion phenomenon with Li electrolyte in $D_2O$ is interpreted as follows: While the electrolysis proceeds, the Pd cathode occludes the deuterium in it and also forms a layer of PdLi alloy and Li metal on the surface of the cathode. The deuterium in the cathode has in-homogeneity in density highest near the surface in a steady condition. The inhomogeneity of the duodenum density and the surface layer of PdLi layer work as a wall to trap thermal neutrons in a sample. A preliminary period necessary to realize cold fusion recognized sometimes in experiments[2-3] may be interpreted as a time necessary to form such a structure in the cathode to trap neutrons.

With this picture of processes occurring in the experiment, we can give probable dependence of $Q$ on parameters appearing in the relation (1) to compare with that obtained in the experiment.

Let us write down pertinent reactions:

$n + {}^6Li = {}^4He\ (2.1\ MeV) = t\ (2.7\ MeV),\quad Q_1 = 4.8\ MeV,$ (2)

$n + {}^7Li = {}^8Li = {}^8Be\ (1.2\ keV) + e^-\ (13MeV) + \underline{\nu}_e$ (3)

${}^8Be = {}^4He\ (1.6\ MeV) + {}^4He\ (1.6\ MeV),\quad Q_1' = 16.2\ MeV,$ (4)

$t + d = {}^4He\ (3.5MeV) + n\ (14.1\ MeV),\quad Q_2 = 17.6\ MeV.$ (5)

Here, we assume the presences of the trapped neutron in the sample and $^6$Li in the electrolyte where its natural abundance is 7.5 %. We will denote the energies liberated in the reactions (2), (3) + (4), and (5) by $Q_1$, $Q_1'$ and $Q_2$, respectively.

Then, the total excess energy $Q$ and the numbers $N$ and $N'$ of the reactions (2) and (3), respectively, in unit time are given as follows:

$Q = NQ_1 + N'Q'_1 + N\{P_2\ (Q_2 + Q_3) + P'_2(Q_2 + Q_3')\}.$ (6)

$N = 0.35 N_n v_n \rho_{Li6} l_0 S \sigma_{nL6}$ (7)

$N' = 0.35 N_n v_n \rho_{Li7} l_0 S \sigma_{nL7}$ (8)

In the relation (6), constants $P_2$ and $P'_2$ are probabilities of the occurrence of the reaction (5) after a reaction (2) in the sample and in solution, respectively. The energy $Q_3$ and $Q_{3'}$ are the whole energies generated successively in the sample and in solution, respectively, initiated by a neutron with 14.1 MeV produced in the reaction (5).

In the relations (7) and (8), $0.35 N_n v_n$ is the flux density of the thermal neutrons (cm$^{-2}$ s$^{-1}$), $N_n$ and $v_n$ are the density and the thermal velocity of the trapped neutron, respectively, $l_0$ and $S$ are the width and the area of the surface layer of the cathode where Li atoms are precipitated forming PdLi alloy and Li metal layer, $\rho_{Li6}$ ($\rho_{Li7}$) is the density of $^6$Li ($^7$Li) nucleus in the layer. Furthermore, $\sigma_{nL6}$ ($\sigma_{nL7}$) is the fusion cross section of the thermal neutron with $^6$Li ($^7$Li) nucleus

## 3. Physics of cold fusion in electrolysis experiments

We will consider a cycle of reactions started from the reactions (2) and (3).

First of all, we notice in the experimental data that the observed points[8)] of the excess power density (J m$^{-3}$s$^{-1}$) at x = 0.93 are dispersed between 1.5 and 5.5 with its average about 4.5 W/cc. The average value is similar to that in another experiment[3] where the density of trapped neutrons had been determined as $10^{12}$ — $10^{13}$ cm$^{-3}$. Therefore, we may suppose the density of the trapped neutrons in the sample to be $10^{12}$ — $10^{13}$ cm$^{-3}$, though we don't use this value hereafter.

Next, we will consider the first factor, the dependence on the current density, in the relation (1).

The excess energy is proportional to $N_n$ and $\rho_{Li}$, where:

$$\rho_{Li} = \rho_{Li6} + \rho_{Li7}$$

as we can see in the relations (6), (7) and (8). Now, the density of the trapped neutron $N_n$ depends on other parameters because the neutron is lost by the fusions with $^6$Li and $^7$Li, by going out from the sample, is supplied by $t$—$d$ and $d$—$d$ fusion reactions in the sample, etc. In a situation where the excess heat is produced stationarily, $N_n$ and $S$ should be constants. On the other hand, we may assume that the current density of electrolysis is proportional to $S$ in the surface layer. Therefore, the excess energy is proportional to the current density in this situation where the above assumption is valid and the density of the trapped neutron is insensitive to the current:

$$Q \propto i$$

(This situation occurs where the trapping condition does not change rapidly.)

The threshold value $i_0$ depends on the condition to keep $N_n$ constant for stationary production of excess energy. Where $i$ is too small to feed deuteron and lithium atoms to the cathode, formation of the wall to trap neutron will be insufficient to keep the neutrons in the sample.

Third, let us consider the second factor, the average relative density of deuterium $x$ in the sample. The density of trapped neutron $N_n$, depends on the distribution of the deuteron density $N_D$ in the sample. In the case of experiments[8], the distribution is not necessarily uniform. In such a case, the unbalance of $N_D$ works positively to trap neutrons in the sample; the larger the unbalance, the higher the density of trapped neutrons. On the other hand, the larger $N_D$, the larger inhomogeneity of $N_D$ in short time experiments. Therefore,

$$N_n \propto x.$$

Because the width of the surface layer $l_0$ is also proportional to $N_D$ in this situation the excess energy is proportional to the product of $l_0$ and $N_n$, and therefore is proportional to $x^2$

$$Q \propto x^2.$$

The threshold value $x_0$ is determined, again, by a condition to trap neutrons effectively in the sample. It is conceivable that the trapping is ineffective until $x$ reaches a value to make the unbalance of deuteron distribution large enough to work for the neutron trapping.

Fourth, we will take up the third factor $|\delta x/\delta t|$. This is rather easy to understand, the higher the speed to occlude deuterons, the larger the inhomogeneity of deuteron distribution which is effective for the trapping of neutrons. Then, $|\delta x/\delta t|$ determines $N_n$ in the sample. Therefore, $Q$ increases in proportion to $|\delta x/\delta t|$:

$$Q \propto |\delta x/\delta t|.$$

Combining three relations deduced above, we obtain the relation (1), taking into consideration the fact that these factors are not independent.

## 4. Conclusion

The qualitative investigation given above shows how the empirical relation deduced from elaborate experimental works is understood consistently with other data obtained in completely different experiments[1–3].

A basic concept "neutron affinity of lattice nuclei" had been proposed to explain the existence of the trapped neutron in the lattice[9]. The concept should be justified its validity by statistical treatment of a system composed of neutrons and lattice nuclei, finally. Though this program of the justification is not accomplished yet, the TNCF model applied to various cold fusion phenomena showed its ability giving consistent understanding of them. This is, in our opinion, the demonstration of the validity of the concept assumed in the model, reversely.

Now, it is impossible to deny the cold fusion phenomenon having excellent experimental data in various materials. Furthermore, a consistent explanation of the cold fusion phenomenon by the conventional physics demonstrates clearly a facet of the physics of cold fusion. The more careful determination of experimental parameters appearing in the model will make the physics more definite.

## References

(1) R. Bush and R. Eagleton, "Evidence for Electrolytically Induced Transmutation and Radioactivity Correlated with Excess Heat in Electrolytic Cells with Light Water Rubidium Salt Electrolytes," *Trans. of*

*Fusion Technol.* **26**, 344 (1994).
(2) Y. Arata and Y.C. Zhang, "A New Energy caused by 'Spillover-Deuterium'," *Proc. Jpn. Acad.,* **70B**, 106(1994); Y. Arata and Y.C. Zhang, "Achievement of Solid-State Plasma Fusion ('Cold Fusion'), *Proc. Jpn. Acad.*, **71B**, 304 (1995).
(3) M.H. Miles, R.A. Hollins, B.F. Blush and J.J. Lagowski, "Correlation of Excess Power and Helium Production During $D_2O$ and $H_2O$ Electrolysis Using Palladium Cathodes," *J. Electroanal. Chem.* **346**, 99 (1993); M.H. Miles, B.F. Bush and J.J. Lagowski, "Anomalous Effects Involving Excess Power, Radiation, and Helium Production during $D_2O$ Electrolysis Using Palladium Cathodes," *Fusion Technol.* **25**, 478 (1994).
(4) H. Kozima, "Excess Heat and Helium Generation in Cold Fusion Experiments," *Cold Fusion* **17**, 4 – 7 (1996), ISSN 1074-5610.
(5) H. Kozima, "Elemental Transmutation in Biological and Chemical Systems," *Cold Fusion* **16**, 30 – 32 (1996), ISSN 1074-5610.
(6) H. Kozima, S. Watanabe, K. Hiroe, M. Nomura and M. Ohta, "Analysis of Excess Heat and $^4He$ Generation in Pd-Black Cathode by $D_2O$ + LiOH Electrolysis," *Proc. Jpn Acad.* , (to be submitted).
(7) H. Kozima, S. Watanabe, K. Hiroe, M. Nomura and M. Ohta, "Analysis of Data Obtained in Cold Fusion Experiment Producing Excess Power and Helium," *J. Electroanal. Chem.,* (1996) (to be submitted).
(8) M. C. H. McKubre, S. Crouch-Baker and F. L. Tanzella, "Conditions for the Observation of Excess Power in the D/Pd System," *Proc. ICCF5* (April 9—13, Monte-Carlo, Monaco), 17 (1995); also in *Proc. 3rd Russian Conference on Cold fusion and Nuclear Transmutation* (Oct. 2—6, 1995, Sochi, Russia) (to be published).
(9) H. Kozima, "Neutron Band, Neutron Cooper Pair and Neutron Life Time in Solid," *Proc. 3rd Russian Conference on Cold Fusion and Nuclear Transmutation* (Oct. 2—6, 1995, Sochi, Russia) 224 – 237 (1995).

*Hideo Kozima*