Mechanisms of Cold Fusion : Comprehensive Explanations by The Nattoh Model

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Abstract

The phenomena of cold fusion seem to be very complicated; inconsistent data between the production rates of heat, neutrons, tritiums and heliums. Our thoughts need to drastically change in order to appropriately understand the mechanisms of cold fusion. Here, a review is described for the Nattoh model, that has been developed extensively to provide comprehensive explanations for the mechanisms of cold fusion. Important experimental findings that prove the model are described. Furthermore several subjects including impacts on other fields are also discussed.

Keywords

Nattoh model, hydrogen-catalyzed fusion reaction, iton, gravity-decay, multiple-neutrons, tiny blackhole, tiny whitehole

1. Introduction

Since Pons and Fleischmann and Jones *et al.* independently published works on cold fusion (1, 2), many experiments have been carried out over the world to verify whether the fusion reactions can really take place in a metal at room temperature (3 -6). Since deuterium gas is charged into the metal, the conventional D-D fusion reactions were initially expected to occur in the metal by any unknown mechanisms, that are familiar in the high temperature plasma physics, are written as follows,

$$\mathrm{D+D} \longrightarrow {}^{3}\mathrm{He}+\mathrm{n} \tag{1}$$

$$\longrightarrow \mathrm{T}+\mathrm{p} \tag{2}$$

$$\longrightarrow {}^{4}\mathrm{He}+\gamma \tag{3}$$

Here the reactions of Eqs. (1) and (2) take place with the approximately equal probability, but the third reaction of Eq. (3) is about 10^7 times less than the formers. Therefore the particles of neutrons, tritiums, and heliums were enthusiastically searched to explain anomalous heat production in metal. Although the data obtained so far show deviations between the studying groups, they are gradually converging. It has at

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least been made clear that the phenomena of cold fusion is too complicated to be explained by the conventional D-D fusion reactions by the following reasons.

(a) The excess heat production was accurately measured by many researchers (3-6). Those amounts are extraordinarily large so that they cannot be explained by the conventional chemical reactions.

(b) The neutron production was observed by many researchers (3-6). The measured neutron energy is verified to be about 2.5 MeV that is consistent with that produced by Eq. (1) (2). However, the production rate of the neutrons is 10^{12} to 10^{13} times less than that was calculated from the excess heat production based on Eqs. (1) and (2).

(c) The tritium production was also measured by many researchers (3-6). The production rate of the tritiums is 10^4 to 10^8 times higher than that of the neutrons (7). Partially because the tritium measurement is more difficult, there exist large discrepancies between the experimental data. This rather suggests that there might be a systematical reason.

(d) The helium production was also measured by the small number of groups (8). Unexpectedly, instead of ^3He, shown by Eq. (2), a lot of ^4He was produced. Helium -4 might be produced by Eq. (3), but the reaction is associated with the gamma ray. The amount of ^4He seems to roughly correspond to the production rate of the excess heat so that if the reaction of Eq. (3) predominantly occurred, the energetic gamma rays should be intensely emitted. However, such gamma rays could not be observed experimentally.

(e) The energy spectrum of the charged particles, such as protons and heliums, was measured by the few groups (9). The charged particles showed the complicated spectrum that cannot be expected by Eqs. (1) and (2).

(f) Ordinary water is available to cold fusion to produce excess heat (10-13). This is surprising because the cross section of the H-H fusion reaction is about 10^{12} times less than that of the D-D reaction, and is extremely important for industrial applications of cold fusion.

(g) Many extraordinary phenomena associated with cold fusion were reported (14-23). For example, microsparks were observed on the metal surface(22), and strange particles and waves were recorded on the nuclear emulsions (14-21). Recently, a metal hydride of palladium showed the good conductivity in a high hydrogen ratio (23).

In order to explain the mechanisms of cold fusion, many hypothetical models were proposed (3-6). Some are based on conventional reactions and others on new reactions, whether they are chemical or nucler reactions. A good model should comprehensively explain all the phenomena of cold fusion mentioned above. Almost all models seem to be only trying to enhance the conventional D-D fusion reactions or the somewhat modified reactions in the metal in order to explain the extraordinary phenomena of (a) and (b). Even if they could succeed, they should answer much more difficult questions such as (c) to (g). It seems that slightly modified conventional theories cannot comprehensively explain these complicated phenomena. Now our thoughts on cold fusion should be changed drastically. How can we arrive at the right answer?

By seeing the sun rise from the east and set in the west, the Ptolemaican theory simply states that the sun moves around the earth. It is somewhat inevitable to us that we have the Ptolemaican theory for any new phenomena because we have to protect ourselves from them. By changing our way of thinking from the Ptolemaican to the Copernican theories, we are now going to understand not only the behaviors of the planets but also the origin of the universe. For cold fusion, on the other hand, we are now in the era of the Ptolemaican theory. Since the deuterium gas is charged into the metal, we are convinced of the conventional D-D fusion reactions, whichever one is for or against cold fusion. We should change our way of thinking to the Copernican theory in which our view point also moves around hydrogen atoms.

The author earlier proposed the Nattoh model ("nattoh" means fermented soybeans in Japanese) that introduces a new "hydrogen-catalyzed" fusion reaction(24-26). The new reaction occurs in hydrogen-clusters that are formed in tiny spaces in the metal, such as grain-boundaries, defects and interfaces. The hydrogen-clusters can be compressed by themselves in a highly pressurized state of the hydrogen atoms, in which new particles "itons" are produced. Energetic hydrogen atoms that can instantaneously be emitted during the hydrogen-catalyzed fusion reaction make additional fusion reactions. This means that the chain-reactions of hydrogen can be maintained in metal. The sequential reactions of the hydrogen-catalyzed fusion reaction are primary for cold fusion, especially for the Pons-Fleischmann method. Furthermore, since the hydrogen-cluster can contain many hydrogens, possibly many millions, many strange reactions are associated with the primary reactions: productions of heavy elements and multiple-neutron nuclei, formations of tiny black and white holes and so on. Readers will easily understand that cold fusion is a small scale simulation of the events that occur in cold stars far away in the universe. By accepting the Copernican theory for cold fusion, we can microscopically arrive at the same position as the origin of the universe.

This paper describes comprehensive explanations by the Nattoh model for the mechanisms of cold fusion, especially Pons-Fleischmann type experiments and important experimental evidences that verify such explanations.

2. Mechanisms of Cold Fusion

Let us briefly consider a fission reactor. There the principle is well known: fission reactions of uranium and/or plutonium are maintained by chain-reactions of neutrons. However, this answer is only 50% correct. There are various additional reactions associated with the primary fission reactions: various neutron-induced reactions, beta-decays of fission products and so on. If detectors are located near the fission reactor core, various kinds of radiations could be measured.

The situation of cold fusion might be similar to the fission reactor. The phenomena of cold fusion seems to be very complicated. But unexpectedly the principle might be simple. When the reactions are appropriately arranged in order, the mechanisms of cold fusion can be well understood.

The mechanisms of cold fusion are summarized in Fig. 1. The processes of cold fusion can be classified into two categories: primary and associated reactions. The primary reactions are the hydrogen-catalyzed fusion reactions that contain both of the intra- and inter-cluster reactions. The former means the new hydrogen-catalyzed fusion reactions and the latter the chain-reactions of the hydrogen atoms, respectively. The associated reactions involve the conventional D-D fusion reactions and the other branches of the many-body fusion reactions induced in the hydrogen-clusters. Further reactions are mainly induced by the production of the multiple-neutrons. The rate of the reactions shown in Fig. 1 depends on experimental conditions, especially the current density and the pressure of hydrogen. As the current density or the hydrogen pressure increase, the reactions shown in the lower part of the figure can be highly enhanced.

2. 1 Primary Reactions

(a) Hydrogen-Catalyzed Fusion Reaction (24, 25)

The primary reactions of cold fusion are the hydrogen-catalyzed fusion reactions that occur in the hydrogen-cluster. The hydrogens that diffuse from the metal surface are trapped inside and outside the lattice in the metal. The former hydrogens can take no fusion reactions because they are located in specified positions between the metal nuclei and are too distant to fuse each other. The latter hydrogens are mainly trapped in grain-boundaries to form hydrogen-clusters. The hydrogen-clusters are so pressurized by the overpotential of the electrolysis that they can induce the new "hydrogen-catalyzed" fusion reactions by self-compression. The number of hydrogen atoms contained in the cluster is plural, possibly many millions, so that there are a lot of variations for the hydrogen-catalyzed fusion reactions. This fact makes cold fusion burn in various manners. The most probable among them are the fusion reactions between two hydrogens under the many-body interactions for heavy water as follows,

$$2D+e+D \longrightarrow {}^4He+i_1+{}^2n \tag{4}$$

$$\qquad\qquad \longrightarrow {}^4H+i_1+d \tag{5}$$

$$\qquad\qquad\qquad {}^4H \longrightarrow {}^4He+e+\bar{\nu} \tag{6}$$

for the emission of the single iton i_1, and

$$D+2e+D \longrightarrow {}^4n+i_2+d \tag{7}$$

$$\qquad\qquad \longrightarrow {}^4H+i_2+{}^2n \tag{8}$$

for the emission of the double iton i_2, where ${}^2n$ and ${}^4n$ are multiple-neutrons of di- and quad-neutrons, respectively. Here the number of the electrons and hydrogens that participated in the left side of the equations are very large, so other variations are possible, but with the less probability.

The production of the new particle "itons" is clearly related to the hydrogen-catalyzed fusion reactions, in that the compression of the hydrogen-cluster can be explained by two steps : (1) effective mass of the electrons increases by following the hydrogens to initially shrink the hydrogen-cluster and (2) in the shrunken hydrogen-cluster, the hydrogen nuclei are depolarized to form the itons that further compress the cluster. In the first process, the electrons take an important role. If additional electrons are induced by flowing electrical current or discharging, the compression is more progressed. The new particle "itons" might be consisted of electrons, positrons and neutrinos. The itons cover up the surface of the product particles such as the multiple-neutrons. Much more electrons than positrons are involved in the itons so that the itonic particles have highly negative charges. When the hydrogen-cluster shrinks into the extremely compressed state, the electrons might be localyzed and/or degenerated so that the itons have the mesh structure. On the contrary, the iton takes the de-ionization effects during passing through a material and finally decays to a pair of an electron and a positron.

In the compressed hydrogen-cluster ("itonic particles"), the distances between the nuclei are so short that other fusion reactions can easily take place. For example, more two-body fusion reactions can simultaneously occur within the same hydrogen-cluster. Here the fusion products such as the quad-neutrons can be emitted, combined each other with the itonic networks. Alternatively, many-body fusion reactions such as three and four body-fusion ones also can occur in the compressed hydrogen-cluster. Those reactions provide not only heavy elements but also heavy mutiple-neutrons. They can be classified into the associated reactions, as mentioned before.

There might be an alternative scinario in the second proccess. When the hydrogen-cluster is compressed, only a mesh structure of the electrons might be formed in stead of the formation of the itonic mesh. Even here, the same particles are produced,

$$2D+e+D \longrightarrow {}^{4}He+e+D \qquad (4a)$$

$$\longrightarrow {}^{4}H+D \qquad (5a)$$

$$2D+2e+D \longrightarrow {}^{4}n+D \qquad (7a)$$

(b) Chain-Reactions of Hydrogens

The hydrogen-catalyzed fusion reactions mentioned above emit energetic hydrogens that can make additional fusion reactions in other hydrogen-clusters. These intercluster reactions are the chain-reactions of the hydrogens that can be maintained under the appropriate condition in the metal (25). This is similar to the neutron chain-reactions in a fission reactor. For cold fusion, the hydrogen-clusters are fuels, instead of uranium and plutonium, and the hydrogens are catalyst particles, instead of the neutrons. There are two modes of the burning with the hydrogen chain-reactions : direct and indirect. The former consists of the sequential fusion reactions that occur within the hydrogen-cluster under the slowing down process of the energetic hydrogens, such that the burning is local and bursts. The latter, on the other hand, occurs between the hydrogen-clusters that are located comparably distant each other. Those mode can burn continuously and widely over the metal.

The indirect mode was discussed in detail in the previous paper (25), in that the time behavior of the free hydrogens and hydrogen-clusters are separatively written by two diffusion equations, respectively, as follows,

$$\frac{1}{v}\frac{\partial\phi(\boldsymbol{r},t)}{\partial t}=\mathrm{D}\nabla^2\phi-\sigma_{tp}^{h}N_h\phi+\left(\overline{\nu\varepsilon(N)\sigma_{fu}}+\sigma_{tp}^{h}-\overline{\sigma_{tp}}\right)N\phi+s\delta(\boldsymbol{r}-\boldsymbol{r}_s) \tag{9}$$

and

$$\frac{\partial N(\boldsymbol{r},t)}{\partial t}=\bar{D}\nabla^2N-\bar{\lambda}N+\sigma_{tp}^{h}N_h\phi-(\overline{\epsilon(N)\sigma_{fu}}+\sigma_{tp}^{h})N\phi \tag{10}$$

for the notations, refered to Ref. 24. Equations (9) and (10) are non-linear due to the cross term of the flux ϕ of the free hydrogen and the number density of the hydrogenclusters N. The stationary solution can be obtained for a special case with the flat distribution of the hydrogens and hydrogen-clusters. The critical condition is written as follows,

$$k_{eff}=1 \tag{11}$$

where

$$k_{eff}=\frac{(\sigma_{tp}{}^{h}-\bar{\lambda}_{tp})N}{\sigma_{tp}^{h}N_h}k \tag{12}$$

$$k=\frac{\overline{\nu\epsilon(N)\sigma_{fu}}}{\sigma_{tp}{}^{h}-\bar{\sigma}_{tp}}+1 \tag{13}$$

At the start-up, the power increases exponentially as follows,

$$P=Q\,\overline{\epsilon(N)\sigma_{fu}}\int d\boldsymbol{r}\;N(\boldsymbol{r},t)\,\phi(\boldsymbol{r},t)$$

$$=Q\,\overline{\epsilon(N)\sigma_{fu}}\,V_r\Big[N^*\phi_s+\sum_{n'}A_n{}'e^{-\{\bar{\lambda}+\bar{D}_N B_{Nn'}^2\}t}\phi_s+$$

$$+\sum_{nn'}A_n'A_{n'}e^{-\{\bar{\lambda}+\bar{D}_N B_{Nn'}^2\}t}exp\left\{\phi_{on}t+\frac{\varphi_{1n}}{\bar{\lambda}+\bar{D}_N B_{Nn}^2}(1-e^{-\{\bar{\lambda}+\bar{D}_N B_{Nn'}^2\}t})\right\}\Big] \tag{14}$$

When the hydrogen chain-reactions can be maintained, the excess heat is significantly produced. In order to ignite or keep the chain-reactions, it is essential to provide the dense distribution of the hydrogen-clusters in the metal. This means that there exists the critical concentration of the hydrogens contained in the metal. On the contrary, when a crack and/or spot that quickly reduce the hydrogen concentration are produced, the critical condition is broken. The power drop for a simple case of the symmetrical division can be written as follows (25),

$$P = Q\overline{\epsilon(N)\sigma_{fu}} N^* \phi_s \sum_{nn'} A'_n A_{n'} \int_{V_r} dr \; e^{iB_{Nn'}r + iBr}$$
$$\times e^{-\{\bar{\lambda}+\bar{D}_N B_{Nn'}2\}t} exp\left\{\varphi_{on} t + \frac{\varphi_{10}}{\bar{\lambda}+\bar{D}_N B_{Nn}^2}\left(1 - e^{-\{\bar{\lambda}+\bar{D}_N B_{Nn'}2\}t}\right)\right\} \tag{15}$$

2. 2 Associated Reactions

There are several reactions that are associated with the primary fusion reactions. Since many hydrogens are involved during the hydrogen-catalyzed fusion reaction, very significant reactions that cannot be induced by the high temperature plasma at all are possible.

(a) The conventional D-D fusion reactions of Eqs. (1) to (3) are associated to emit 2.5 MeV neutrons, tritiums and so on. These reactions are induced when the energetic hydrogens that are produced by the hydrogen-catalyzed fusion reactions of Eqs. (5) and (7) bombard near hydrogens in the metal. The conventional fusion reactions certainly take place, but as secondary processes, and it is wrong to consider that they are the primary processes. The rate of the conventional reactions is approximately 10^{12} times less than that of the hydrogen-catalyzed fusion reactions, that is one of the main sources of the excess heat. This is a reason why the production rate of the neutron is extremely less than that calculated from the excess heat. On the other hand, the tritiums also should almost be equally produced as the 2.5 MeV neutrons. As discussed in (c) of Sec. 1, the experimental data show that the production rate of the tritiums is 10^4 to 10^8 times higher than that of the neutrons. This discrepancy will be discussed later.

There is a special case, in which the chain-reaction of the hydrogen-catalyzed fusion reaction does not sufficiently take place but that of the conventioanl fusion reactions is locally ignited in a compressed gas of hydrogen. This case might sometimes occur in an experiment with the zero or low current density. Here the amount of tritiums and 2.5 MeV neutrons are much larger than that of helium-4, so that the conventional fusion reaction looks like the primary process.

(b) Elements can newly be produced during cold fusion. There are three ways of the element production : transmutation from the nucleus of the host metal and electrolyte, many-body fusion reactions of the hydrogens and many-body fission reaction. The first can take place when the hydrogen-cluster surrounds the nucleus of the host metal and electrolyte and is compressed asymmetrically : one or more electrons, hydrogens and oxygens are first captured by the located nucleus. Here, the product elements are often heavy and are distributed near the original nucleus. For example, elements of ^{40}Ca and ^{115}In can be produced from the electrolyte K and host metal Pd, respectively,

$$^{39}K+p \longrightarrow {}^{40}Ca \tag{16}$$

$$^{41}K+{}^{16}O \longrightarrow {}^{57}Co \xrightarrow[EC]{} {}^{57}Fe \tag{17}$$

$$\begin{pmatrix} ^{108}Pd \\ ^{110}Pd \end{pmatrix} + 6D \longrightarrow 2\,{}^{115}In \tag{18}$$

On the other hand, the electron capture can less contribute to the nuclear transmutation, because the product often returns back to the original nucleus by the beta decay.

Secondly, comparatively light elements also can be produced by the many-body fusion reactions of the hydrogens in the compressed hydrogen-clusters. For example,

$$3D \longrightarrow {}^{6}Li \tag{19}$$

$$4D \longrightarrow {}^{8}Be \longrightarrow 2\,{}^{4}He \tag{20}$$

$$5D \longrightarrow {}^{10}B \tag{21}$$

These elements are sequentially distributed from lithium to around iron. As the burning is more violent, heavier elements can be produced. Thirdly, the many-body fusion reaction also can contribute to the nuclear transmutation, as will be discussed in (d).

It is remarkable that the nuclear transmutation occurs without radiation. All of the reactions from (16) to (21) take place in the itonic particle so that excited energy of the compound nucleus is transferred to the vibrating motion of the itonic mesh. Furthermore it is important to keep in mind that among the nuclear transmutation reactions there are reactions with the negative Q value. This is a case of that much heavier elements such as Fe are produced when the hydrogen capture proceeds.

(c) Multiple-neutron nuclei can be produced during cold fusion. The di-and quad-neutrons can be produced by the primary processes of Eqs. (4) and (7). Furthermore, the intermediate multiple-neutrons such as ^{6}n and ^{8}n can be produced by the manybody fusion reactions as follows,

$$3D+3e+D \longrightarrow {}^{6}n+i_3+d \tag{22}$$

$$4D+4e+D \longrightarrow {}^{8}n+i_4+d \tag{23}$$

Heavy multiple-neutrons, more than 30 neutrons, can be produced by compressing the nuclei of the electrolyte and host metal surrounded by the hydrogens, as follows,

$$^{A}K+Ae+D \longrightarrow {}^{A}n+i_A+d \tag{24}$$

$$^{A}Pd+Ae+D \longrightarrow {}^{A}n+i_A+d \tag{25}$$

Those multiple-neutrons are covered up by the itonic mesh so that they cannot scatter out individual neutrons. Rather they are metastable for a moment and shrink to finally undergo the gravity decay.

(d) Nuclear reactions are caused by the bombardment between cold fusion product particles such as the multiple-neutrons and the nuclei of the surrounding materials. When the multiple-neutron enter the nucleus, the exciting energy of the compound nucleus is expected to be so large that a nuclear reaction with several energetic fragments can be induced. This is the many-body fission reaction. The reaction is also possible with light nuclei such as silver that can induce no fission reaction with the ordinary neutron. And heavy elements also can be produced as fission products, that might be somewhat radioactive. The many-body fission reaction is observed like a star on nuclear emulsions.

(e) "Gravity-decay" (referred to distinguish the microscopic phenomena from the universal "gravitational collapse") can be caused by the multiple-neutron. When the multiple-neutron is produced, it is covered up with the itonic mesh by that the constituent neutrons cannot be scattered out. Rather by the compression force of the itonic mesh, the multiple-neutron is completely distroyed and shrinks to an extremely tiny particle. Finally the multiple-neutron transforms to a tiny blackhole. The tiny blackhole instantaneously evaporates by emitting radiations and/or extremely tiny particles. On the other hand, the materials absorbed in the tiny balckhole are violently destroyed and are emitted from a whitehole through a wormhole that connects both of the holes.

It seems difficult to accept that the blackhole can be generated in the cell, because it is usually considered that the blackhole in the universe needs a mass 10 times over than that of the sun. The fact is contrary. Since the gravitational force is employed to compress and completely destroy an assembly of neutrons, the extremely heavy mass is required. The gravitational force is the weakest among four naturally existing forces. However, if the electromagnetic force is effectively employed, it is easier to generate a tiny blackhole, since the electromagnetic force is about 40 orders stronger than the gravitational force. Here the tiny blackhole is not black in the accurate meaning, but is so light that cannot prevent the light from escaping from the hole.

2. 3 Surface Reactions

Unlike in the metal, the situations become more complicated on the surface : (a) chemical reactions deposit materials such as the electrolyte, (b) overpotential highly compresses the hydrogen-clusters and (c) local discharge enhances the hydrogen-catalyzed fusion reactions. Among them, the chemical reactions are conventional.

(a) Surface Reactions

There is a variation in cold fusion that predominates on the surface of the metal. This is significant for the metal with low hydrogen permeability, such as nickel. Here the hydrogens cannot penetrate deeply so that the hydrogen concentration of the surface increases. And the hydrogens that can freely move around on the metal surface gather in tiny pits to form large hydrogen-clusters. Furthermore they are intensely compressed by the overpotential of the electrolysis to induce the hydrogen-catalyzed fusion reactions. If the voltage is increased, the high compression can produce tiny black and white holes. Here the chain-reactions of the hydrogens are somewhat limited by the hydrogen leak from the surface. The sequential reactions can be maintained externally by electrolysis. Therefore the excess heat can be released as soon as the electrolysis starts. The nuclei of the host metal and electrolyte also can be burn by surrounding them with the hydrogen-clusters.

(b) Discharge

There are small and local discharges on the surface, even when the electrolysis is continuously maintained. They might occur around irregular points on the electrodes, such as in the pits. The discharges can accelerate the compression of the hydrogen-clusters to enhance the hydrogen-catalyzed fusion reactions. Also they often burst to induce gas explosions.

2. 4 Ordinary Water

It is very important for industrial applications that ordinary water is available to cold fusion. The mechanisms of cold fusion with ordinary water is same as with heavy water, except different elements are produced. The cross section of the H-H fusion reaction is 10^{12} times lower than that of the D-D one, but it does not matter, since cold fusion is based on the different reactions. The most probable reactions for ordinary water that correspond to Eqs. (4) and (7) for heavy water are written as follows,

$$2H+e+H \rightarrow {}^{2}He+i_1+{}^{1}n \tag{26}$$

$${}^{2}He \rightarrow D + e + \bar{\nu} \tag{27}$$

$$2H+e+H \rightarrow D+i_1+p \tag{28}$$

for the emission of the single iton i_1 and

$$2H+2e+H \rightarrow {}^{2}n+i_2+p \tag{29}$$

$$2H+2e+H \rightarrow {}^{2}He+i_2+{}^{2}n \tag{30}$$

for the emission of the double iton i_2. The prediction of ${}^{2}He$ might be contradicted with the Pauli's selection rule, but allowed for a short time because two protons are compulsorily compressed by the itonic mesh. For ordinary water, proton and deuterium are the main products, that can induce the chain-reactions similar to heavy water. And instead of the quad-neutron for heavy water, the di-neutron that undergoes the gravity decay is produced. The "single" neutron is also produced, but it might be different from the ordinary neutron; the single neutron produced here is covered by the itonic mesh and collapses rapidly.

The reactions of the hydrogen-clusters from Eq. (26) to (30) produce no radioactive elements. However higher reactions generate those wastes that might be trouble some for industrial applications. For example, tritiums can be produced from three hydrogens as follows,

$$3H+2e+H \longrightarrow T+ i_2+p \tag{31}$$

3. Experimental Evidence

Almost all researchers who believe the conventional theory have orthodoxically been looking for experimental evidence such as the heat and the fusion products of neutrons, tritiums and heliums (3-6). However, cold fusion is based on the different reactions, therefore other experimental evidences should be researched. The author has been searching for such experimental evidencce by using a special technique with nuclear emulsions. Unusual particles and phenomena were obtained, which clearly indicate that the mechanisms mentioned in the preceding section actually take place. In this section, the experimental evidence that was obtained mainly by the author's experiments is described.

3. 1 Experiments

Many cold fusion experiments using the electrolysis method were carried out by the author (10, 13-22, 27, 28). Ordinary and heavy waters were used as electrolyte solutions mainly mixed with potassium carbonate and sodium chloride. Metals of palladium, nickel, titanium and copper were often used as the cathode and everytime platinum was used as the anode, respectively. Two kinds of cylindrical glass cells were used for the anodes of rod and foil metals. The anode of the rod metal that were surrounded by the helical cathode of platinum was totally inserted in the electrolyte solution. Nuclear emulsions (100 μm thick MA-7B made by Fuji Film Inc.) were often used to observe emitted particles. The nuclear emulsions were set outside the glass cell. On the other hand, for foil method, one of the foil surfaces was contacted with the electrolyte solution and the other with nuclear emulsions in the atmosphere. Here emitted particles from the metal foil can directly be recorded on the nuclear emulsions. Furthermore, optical and scanning electron microscopes (SEM) with energy dispersive X-ray spectroscopy (EDX) were mainly used to analyze the metal structure and fusion products.

3. 2 Hydrogen-Clusters

The hypothesis that the hydrogens form the clusters in the small space to induce the hydrogen-catalyzed fusion reactions is the fundamental consideration of the Nattoh model. Much experimental evidence clearly indicated that the hydrogen-clusters are really formed and that the fusion reactions really take place in the compressed clusters. The first is the break up of the itonic hydrogen-clusters. The hydrogen-clusters that are extremely compressed are covered up by the itons. They are further compressed to form heavy multiple-neutrons by the completely symmetrical compression. However if it is not complete, for example, one or more fusion reactions precede in the cluster, the hydrogen-cluster might break up. Much experimental evidence suggesting the break up of the itonic hydrogen-clusters were recorded on copper metals during the discharging experiments with pin cathodes (28). Then among the broken itonic hydrogens, there were observed evidences of the fusion processes. The number of the hydrogens contained in the cluster depends on the conditions such as applied voltage and current. For high voltage, such as around 100 V, the number of the contained hydrogens might be more than millions. Traces of the broken hydrogen-clusters containing many hydrogens were observed on the copper plate.

Secondly, the itonic meshes covering the hydrogen-cluster faded while passing through the material so that the linkages of the individual hydrogens become weaken and finally scatter. This is a reverse process of the compression of the hydrogen-cluster. Those evidences were also observed on the back surface of the nickel thin foil, referred to the "hydrogen-frost"(13). They seem to have some structure like solidified vapor.

3. 3 Primary Fusion Products

The most probable reactions during the cold fusion are shown by Eqs. (4) to (8) for heavy water and Eqs. (26) to (30) for ordinary water. For the latter, the charged particles of the electrons, protons and deuteriums that are primary fusion products were clearly observed on the first nuclear emulsion that was contacted with the nickel cathode (13). And the di-neutrons were also measured on the nuclear emulsions and on the metal surface (13, 28). The single neutrons also underwent the gravity decays because they were covered with the itonic mesh. Those traces were separately observed on the metal surface during the one-point discharge experiments (28). For heavy water, on the other hand, no charged particles of the primary products were observed on the nuclear emulsions, because a thin protection sheet was located over the first nuclear emulsion. But Miles *et al.* measured a lot of ^{4}He instad of ^{3}He by the chemical method (8), as predicted by the Nattoh model. And the di-and quad-neutrons were successfully observed on the nulcear emulsions (A micro-explosion that was caused by the gravity decay of the quad-neutron was first observed on August 25 in 1990 on a nuclear emulsion that was located outside of the glass cell in the experiment of palladium rod/heavy water mixed with sodium chloride, shown in Fig. 1 (21)). They are covered up with the itonic meshes that are broken at the explosion of the inner multiple-neutrons. Remarkable traces indicating the explosions of the quad-neutrons associated with the break up of the itonic meshes were found (20). Furthermore a trace indicating that four fusion reactions simultaneously occur in the hydrogen-cluster was also observed (18).

3. 4 New Particle "Itons"

The Nattoh model predicts the production of the new particle "itons" during the hydrogen-catalyzed fusion reactions. The itons are considered to consist of electrons, positrons and neutrinos. Since more electrons than positrons are involved, the itons are negatively charged. When the itons are produced during the compression process of the hydrogen-cluster, they are emitted to cover up the nuclei of the product particles. Figure 3 in Ref. 20 clearly shows the break ups of the itonic products, inside that the quad-neutron underwent the gravity decay. While the iton passes through the material, the electrons of the iton are torn off by a de-ionization process and the iton finally decays to a pair of an electron and a positron. The sequential break ups of the network of the itonic meshes were successfully observed on the nuclear emulsions, shown in Fig. 4 in Ref. 20. And the pair productions due the itons were also recorded on the nuclear emulsions (14).

3. 5 Chain-Reactions

The Nattoh model predicts that the chain-reactions of the hydrogens can be maintained to predominately produce the excess heat for the Pons-Fleischmann type experiment. And the critical equation for the indirect mode was obtained, Eqs. (11) to (13). It is difficult to obtain experimental evidence that directly prove the occurrence of the chain-reactions in metal. However there is data suggesting it. First, a critical value seems to exist for the atomic ratio of D/Pd, that needs to be over 0.85 in average to ignite the burning (6). Under that value, cold fusion cannot be induced at all. Second, the time behavior of the power can be well presented by Eq. (14) : it approaches exponentially to the constant level that can be determined by the surface condition.

3. 6 Heavy Element Production

The EDX analyses with SEM indicated that there are heavy elements distributed in the grain-shaped defects (21). They consist of wide and continuous nuclei ranging from sodium to zinc (the EDX system is not available to lighter elements than sodium) so that they can be assigned to be produced by cold fusion processes. The Nattoh model predicts that the many-body fusion reactions can easily take place in the compressed hydrogen-clusters to produce the heavy elements. During the explosive cold fusion, the burning was violent so that those heavier elements could be easily produced. The neutron-induced radioactive method found that the isotope of ^{115}In was produced (29). This was caused by the nuclear transmutation of the host metal Pd, shown in Eq. (18). On the other hand, Bush reported that Ca was produced from K during the electrolysis of ordinary water with thin nickel foil, as shown in Eq. (16)(12). Ohmori *et al.* reported the production of Fe on the surface of Au electrode, as shown in Eq. (17)(30). Furthermore Kucherov *et al.* reported the production of 23 nuclei ranging from He to Ru (31). Here the many-body fission reaction should be involved.

3. 7 Multiple-Neutrons

The Nattoh model predicts the production of the multiple-neutrons such as di- and quad-neutrons during the hydrogen-catalyzed fusion reactions. The di-and quad-neutrons are the primary products of cold fusion with ordinary and heavy water, respectively. Those traces were observed on the nuclear emulsions, described in Sec. 3.3. Since many hydrogens are involved in the hydrogen-clusters, the other branches for the production of heavy multiple-neutrons might be possible. Although extremely heavy mutiple-neutrons can be trasformed to the tiny blackholes, as described in Sec. 3.9, intermediate multiple-neutrons such as ^{6}n and ^{8}n might be produced. They also are compressed by the itonic meshes to explode. Traces suggesting those explosions were found on the nuclear emulsions (17).

3. 8 Defects in Metal

Metals that were used for the cold fusion experiments were analyzed by SEM (27). Strange defects were observed in the grain-boundaries in the metals: spot and grain-shaped defects. The spot defects suggest one-dimensional burning of the cold fusion and by those sequential reactions, the grain-shaped defects are formed. They are arranged in the grain-boundaries so that these defects verify that as the Nattoh model predicts, the cold fusion reactions occur not in the lattice but in the grain-boundaries in that the hydrogens can be trapped to form the hydrogen-clusters.

3. 9 Many-Body Fission

The multiple-neutrons such as di- and quad-neutrons that are predominately emitted during cold fusion are expected to interact with nuclei in the surrounding materials to induce nuclear reactions. The compound nuclei caused by the multiple-neutrons might have a higher exciting energy than by the ordinary neutron. Therefore nuclear fission reactions with many fragments might be possible.

Stars indicating those reactions were obtained in an experiment with palladium foil and heavy water (19). The traces were recorded on the nuclear emulsions located outside the cell. They can be clearly distinguished from the stars caused by the cosmic rays. The stars suggest that the multiple-neutrons induced the many-body fission reactions with heavy nuclei, probably silver, in the nuclear emulsions. The number of the fragments was around seven or eight, and they might somewhat contain radioactive nuclei. The many-body fission reaction should more frequently take place in the cell and somewhat contribute to the heat production and the nuclear transmutation.

3. 10 Tiny Black and White Holes

When the nuclei of the host metal and the electrolyte are compresssed in the hydrogen-cluster, more than 100 neutron nucleus can be produced that might be transformed into a tiny black hole by the gravity decay. The extraordinary trace shown in Fig. 4 in Ref. 18 indicates that a tiny black hole is produced and rolling in the neighboring materials. Due to the light mass, the tiny black hole evaporates instantaneously, as shown in Fig. 1 in Ref. 18.

The black hole is connected with a white hole from which the absorbed materials can be sprouted out. Many tiny white holes were observed in experiments with low hydrogen permeability such as nickel (13). Figures in Ref. 13 show those tiny white holes, in that the broken materials are sprouting from the top of the cone. Remarkably, Fig. 7(i) in Ref. 13 shows both of the evaporation of the black hole and the sprouting of the materials from the white hole. They might have been divided while passing through a warm hole that connects the black and white holes.

It is now uncertain what materials can be sprouted from the white hole. Since the nuclei are destroyed by the gravity decays and the broken materials pass through the worm hole of the order of 10^{-33} cm so that they might at least be non-baryons, and consist of the tiny particles such as superstrings. The linked materials can somewhat be seen in the exit of the white holes (13). Furthermore traces suggesting that some heavy particles such as X-particle might have been emitted were observed on the nuclear emulsions (13, 20). Those pictures were published in a book (32).

3. 11 Miscellaneous

Several extraordinary phenomena were found during cold fusion. The first is strange microsparks that were observed on the metal surface, such as titanium during the AC electrolysis experiments (22). They can be distinguished from the conventional electrical sparks. The microsparks were found to be related to the tiny black or white holes by setting the nuclear emulsions. Since the electrical charging was continuously employed, the microsparks were shining near the surface like twinkling stars. However during other experiments with the shot charging (33), the microsparks flighted 2 or 3 cm in the solution or air, like ball lightening, and finally stopped to explode. Furthermore strange traces of coupled rings that were suggested to be caused by the tiny ball-lightning were found on nuclear emulsions. They were symmetrically recorded on the first and second nuclear emulsions. This means that the tiny ball-lightning hopped up and down in a small space between the first and second nuclear emulsions. These strange behaviors can be well explained by the characteristics of the itonic hydrogen-clusters.

The second is the extraordinary conductivity that were recently reported by McKubre *et al.* (23). While they were measuring the electrical resistence to know the amount of hydrogens absorbed in a metal, the resistence sharply dropped. According to the Nattoh model, hydrogen-clusters that are locally compressed in small spaces in a metal such as grain-boundaries become the itonic state, that are negatively charged due to the surplus electrons and well conductive. As the hydrogen loading ratio increases, the hydrogen-clusters become densely distributed and interconnects each other. Finally the rod of the metal hydride becomes wholely conductive.

The third is interference phenomena that were also observed on the nuclear emulsions located outside the cell (16). The gravitational and anti-gravitational waves were suggested for them. They should have a weak intensity but might microscopically interact with the material of the nuclear emulsions. But these should be examined in more detail.

4. Discussions

In the preceding sections, the mechanisms of the cold fusion were explained by the Nattoh model and the experimental results that verify the explanations were shown. Here the controversial issues of the cold fusion and the other important subjects are discussed.

4. 1 Controversial Issues

The anomalies of the cold fusion that are controversial issues can well be explained by the Nattoh model.

(a) The primary controversy is the reproducibility of the excess heat. After cold fusion was published, many researchers tried to replicate the experiments. However very few researchers succeeded. Alternatively, even in same laboratories, results depended on experimental conditions, especially used palladium rods. These are caused by the characteristics of the chain-reactions of hydrogens that is a predominate source of the excess heat for metals such as palladium with the high hydrogen permeability. The hydrogen concentration should be increased such that the critical condition of Eqs. (11) to (13) is maintained. However during the charging of hydrogens into palladium, tiny cracks or pits are produced. The absorbed hydrogens rapidly leak from these place. Then the critical condition cannot be satisfied. Alloys of palladium with about 10% silver that protects them from cracking can improve the reproducibility of the excess heat production (6).

On the other hand, with metals such as nickel with the low hydrogen permeability, the main source of the excess heat is the surface reaction. Since the hydrogen-clusters are mainly compressed by the overpotential, the excess heat can be produced as soon as the charging starts. The reproducibility can be expected to be almost 100%. In the case of the Mills type experiment, the chain-reactions of hydrogens contribute less to the heat production than in the Pons-Fleischmann type experiment, because they occur only on the surface. The other reactions such as the nuclear transmutation given by Eqs. (16) and (17) and the gravity decay reactions contribute more to the heat production. The contribution ratio of the reactions depends on the experimental condition. The nuclear transmutation of the Ca or Fe production is predominate in the low voltage or current density. As the voltage or current density increases, the contribution by the reactions shown in the lower part in Fig. 1 becomes more.

(b) The inconsistency between the production rates of the neutrons and the excess heat described in (b) in Sec. 1, are often controversial for heavy water. This can well be explained by the hydrogen-catalyzed fusion reactions that emit no neutrons. For palladium, the main source of the excess heat is the chain-reactions of the hydrogen-catalyzed fusion reactions where the new particle itons are emitted, taking away about 20 MeV from the excited ^{4}He nucleus for heavy water. The channel of the 2.5 MeV neutron emission can not be opened. Furthermore, the multiple neutron nuclei that are produced in the reactions are covered up with the itonic meshes so that the individual neutrons can not be scatted out. However, the conventional D-D fusion reaction of Eq. (1) that emitts 2.5 MeV neutron takes place as a secondary process, about 10^6 times less than the primary hydrogen-catalyzed fusion reactions. Therefore the production rate of the 2.5 MeV neutrons is at least 10^6 times less than that of the excess heat.

A comment should be added for the itonic multiple neutrons. Especially the di- and quad-neutrons that are emitted during the hydrogen-catalyzed fusion reactions have the itonic mesh with heavy negative charges. They are sometimes confused with the conventional neutrons or alpha particles (6). Those multiple neutrons can be detected by the conventional neutron detector such as scintillators and ionization chambers. Here, the multiple neutrons generate by the gravity decay a peak signal with a very narrow width so it could be easily distinguished from the neutron signal with careful attension. Alternatively, they also generate similar signals to alpha particles in the charged particle detectors such as surface barrier detectors. The multiple neutrons can escape out of the cell or filters that can sufficiently stop the alpha particles.

(c) The inconsistency between the production rates of the tritiums and neutrons, described in (c) in Sec. 1, is an important issue for heavy water. The activity of the tritiums is observed 10^4 to 10^8 times higher than that calculated from the neutron production rate. According to the Nattoh model, ^4H is expected to be produced during the hydrogen-catalyzed fusion reactions for heavy water, as shown by Eq. (5). This isotope undergoes the beta-decay such that the activity might be confused with that of the tritium. Although the lifetime of the ^4H isotope is about 10^{-17} sec, it could be stable for a moment since it is covered up with the itonic mesh. Afetr the mesh fades, the beta decay instantaneously occurrs. So far the isotope of ^4H has not yet been observed in the author's experiments with nuclear emulsions. An assembly of the nuclear emulsions was always covered by a thin protection paper that might have prevented the itonic ^4H from escaping. However, other researchers reported extraordinary results that suggest the production of ^4H. An element with a mass between 4.0026 amu of ^4He and 4.0282 amu of D_2 was observed (34).

(d) As described in Sec. 1, a large amount of ^4He instead of ^3He was reported by Miles *et al.* (8). The production of ^4He would be posssible by the conventional fusion reaction shown by Eq. (3). If so, however, the intense high energy gamma rays should be associated. Rather, this fact can easily be explained by the Nattoh model. The reaction shown by Eq. (4), that is the most probable branch during the hydrogen-catalyzed fusion reactions, shows the production of ^4He. The di-neutrons, associated here, are covered by the itonic mesh and quickly undergo the gravity decays. If a neutron detector, such as a liquid scintillator, is located sufficiently near the metal, the survival di-neutrons might be counted. Almost all of the neutron detectors are located in large moderators so that very few signals are produced by the di-neutrons. Furthermore, ^4He can be produced by the beta-decay of ^4H, as shown by Eq. (6).

(e) The complicated spectra of the charged particles, that cannot be explained by the conventional D-D fusion reactions were reported by a thin foil experiment (9). The spectra were explained by introducing the new particle, iton (26): therefore, the multiple neutrons such as the di-and quad-neutrons would be emitted as bare particles. It was later found that they are covered up by the itonic mesh with a heavy charge (20). They might be confused with the conventional charged particles such as the deuteriums and heliums in the thin foil experiment. If these factors are enclosed, the agreement between the experiment and calculation will be better.

(f) It is important that ordinary water is available to cold fusion. Despite that the feasibility cannot be expected by the conventional theory at all, the extraordinary signals indicating cold fusion were first obtained with ordinary water by the anthor (10). And Mills *et al.* reported the excess heat production with ordinary water by using a thin nickel foil (11). The Nattoh model equally predicts the feasibility of cold fusion with ordinary water, as well as with heavy water. The excess heat production with ordinary water with the thin nickel foil is somewhat less than with heavy water in the palladium rod, because the chain-reaction of hydrogens is limitted on the surface in the former case. However, by using the surface reactions, where the nuclear transmutation and the gravity decay reactions contribute to the heat production, many experimental data with the heat production were reported so far (3-6, 30). Many traces that indicate the gravity decays were observed on the nuclear emulsions (13).

(g) Other strange phenomena observed during cold fusion can be partially explained by the Nattoh model. For example the microsparks that were observed on the metal surface can be explained by the formation of the itonic grain (22).

4. 2 Comparison with the Fission Reactor

Let us briefly compare cold fusion with the fission reactor. For the fission reactor, the primary process is the neutron-induced fission reactions of uranium or plutonium and the power is maintained by the neutron chain-reactions. Additionally there are various reactions associated with the neutron chain-reactions: beta decays of the fission products, Cherenkov lights by the beta decay electrons, gamma rays by (n, gamma) reactions and so on. Cold fusion resembles the fission reactor, i.e., the fundamental reactions of cold fusion are the chain-reactions of the hydrogen-catalyzed fusion reactions that are associated with various reactions. The fuel of cold fusion is the hydrogen-clusters and the hydrogens themselves are the chain-reaction particles.

The biggest differences between them are the distance over which the chain-reaction particles can fly and the multiplicity by that they are multified per reaction. The neutrons can fly about 2 m in the fission core, while the hydrogens have very short ranges in metal, only several hundreds μm. And 2.5 neutrons in average are emitted per one fission reaction of uranium or plutonium, however many energetic hydrogens per hydrogen-catalyzed fusion reaction are emitted. This is because the fuel of the hydrogenclusters consist of many hydrogens, possibly more than millions. The former fact makes cold fusion burn very locally. And the latter means that the critical condition can easily be satisfied for cold fusion. Furthermore cold fusion burns more variously. Although the neutron flux in the nuclear reactor is limited to around 10^{14} n/cm^2. sec, the hydrogens in the metal for cold fusion can be densely concentrated. The rates of the associated reactions during cold fusion are so high that the nuclear transmutation such as the heavy element production is more accelerated than in the fission reactor.

It is remarkable that despite of the high production rate of the elements, there are almostly no radiation. This is due to the formation of the itonic mesh that can take away excitation energy of the compund nucleus.

4. 3 Applications

Several applications of the cold fusion technique are promising.

(a) The energy production is the most important at the present time. There are three processes that contribute to the heat production: chain-reactions of the hydrogen-catalyzed fusion reactions, nuclear transmutation and gravity decays of the multiple neutrons. The first is the main source of the excess heat for the Pons-Fleischmann type experiment with the palladium rod, and the two latters for the Mills *et al.* type experiment with the thin nickel foil, respectively. The first that is sustained by the chain-reaction would be good for the efficiency of the heat production to input electrical power but the most difficult for the controllability of the reaction. We should be care that the nuclear transmutation of heavy elements over Fe contributes to the negative energy production. Then the efficiency of the heat production could not be so improved, even if the hydrogen concentration or the current density are efficiently enhanced. The transforming efficiency from mass to energy is the highest for the third process. For scaling up of power, it is required to achieve the high energy density. Then the method based on the third process might be superior.

For cold fusion, burst burning is easier than continuous burning. Burst burning is suitable to vehicle engines such as automobile, ships and space-crafts. It can be performed by several conditions: direct mode of the chain-reactions, overcritical condition of the indirect mode or the surface reactions. The two formers are enhanced in the metal so that the damage of the materials will have unevitable problems. The last that is especially based on the gravity decays of the multiple neutrons might be more efficient to generate the propulsion power.

(b) Nuclear transmutations also might be possible. There are three ways to obtain nuclear transmutations: production of the elements by the many-body fusion reactions, nuclear transmutation from the nuclei of the host metal and the electrolyte and many-body fission reaction. Unlike in the fission reactor, the transmutation rate for cold fusion is very high because the hydrogen concentration is extremely higher than the neutron flux. The elements produced by the first process continuously distribute from lithium to around iron. The second can produce elements near the host nuclei. With the third process, produced elements could be widely distributed.

(c) Nuclear transmutation might be applied to nuclearly incinerate hazardous materials such as nuclear materials and radioactive wastes. The first method of the nuclear incineration would be to use the capturing one or more protons and oxygens as shown in Eqs. (16) to (17). Cesium-137 or strontium-90 would be contained in an electrolyte solution and transuranium elements such as pultonium and neptium would be mixed in electrodes. Simultaneously they could be incinerated by the bombardment with multiple neutrons such as di-and quad-neutrons. In the former process, the nuclear transmutation takes place in the itonic state so that no radiation would be emitted. In the latter process, on the other hand, additional radioactive materials would be somewhat generated.

4. 4 Safety Problems

When cold fusion is applied in the industrial scale, several safety problems should be resolved.

(a) The first is explosions. The explosions were often experienced during the electrolysis cold fusion. They could sometimes be hydrogen gas explosions, that can easily be avoided with usual care. But even under the normal operation, the preceding explosive cold fusion reactions can easily induce the gas explosions. Here the distance between the electrodes is an important factor. If it is too short, local and small discharges can induce explosive cold fusions. More attention should be payed to controlling the cold fusion reactions as well as the chemical reactions.

(b) Second, radioactive materials could be produced by the fission reactions like in the fission reactor. For cold fusion, the many-body fission reactions are induced by the multiple-neutrons such as the di-and quad-neutrons. Furthermore, the reaction of Eq. (31) generates tritium with ordinary water. They are secondary reactions so that those amounts are extremely less than the primary one. But in the industrial applications, the burn up should be so high that the amount of the radioactive materials is somewhat of be a problem. Even if so, the problems might significantly be reduced than in the case of the fission reactor.

(c) The third is related to the gravity decays. They newly generate tiny black and white holes that might radiate the gravitational waves and non-baryon products. These might already exist in the natural environment, since the cold fusion reactions seem to easily take place anywhere. However, they will be additionally produced with the industrial scale by the applications of cold fusion. This is similar to the problems of the radiations or radioactive materials in the fission reactors. The materials themselves might not be so hazardous but if those magnitudes are over the limit, they will become problems. The effects of those strange materials on biological tissues should be examined in detail.

4. 5 Impacts on Other Fields

As mentioned in Secs. 2 and 3, various significant discoveries were made during cold fusion: (1) new hydrogen-catalyzed fusion reactions associated with the itons, (2) heavy elements production by the many-body fusion reactions, (3) gravity decays to generate the tiny black and white holes and so on. These discoveries in cold fusion might significantly impact on other fields.

(a) The iton could open new science and technology for nuclear physics and material science. Since energy concerned with nuclear physics and material science is very different each other, the two fields had no direct connection so far. The iton that locates significantly near the nucleus can directly interact with the nuclei and transfer energy of the nuclei to material lattice. The spatial distribution and energy of electrons in the itonic mesh should be investigated in detail.

(b) Elementary physics might be stimulated, since the gravity decays followed by the tiny black and white holes can be produced in our laboratories. There seems to exist the critical mass that distinguishes the light multiple-neutrons such as quad-neutrons from heavy ones, although the exact value is now unknown. The multiple-neutrons with light mass undergo the gravity decay to explode with shock waves that were observed like bubbles on the nuclear emulsions. The bubbles certainly consist of much smaller particles than quarks. Heavy multiple-neutrons, on the other hand, are transformed to tiny blackholes that evaporate to emit radiation and particles. The particles should be much smaller than the particles of the bubbles. Therefore, there might exist the level for the dimension of the particles. Furthermore the quantum-relativity theory can be examined in detail by experiments in laboratory. A simple question arises: why can the significant reactions such as the gravity decay occur in low voltage electrolysis around several 10 V, although no high energy accelerators, exixting or planning, can induce them at all. The answer is the compression effect of hydrogen-cluster that is essentially caused by many-body interaction. Recently, an accelerator induced cold fusion reactions by accelerating hydrogen-clusters (35).

(c) Extraordinary phenomena were observed in the natural environment so far (36). Many of them are found to be associated with the electrical discharge, but left unexplained. However they also might be made clear by similar mechanisms to cold fusion. For example, tiny ball lightenings were observed during a discharging cold fusion experiment (33).

(d) The astrophysics might modify the senario by the discovery of the new fusion reactions. For example, the solar neutrino problems should be re-examined by inducing the new fusion reactions, because the hydrogen concentration deep in the sun is so high that new fusion reactions can easily be enhanced. Alternatively, the scenario of the element production in the origin of the universe should also be modified. We can remember the events that occur in cold stars faraway in the universe. The prodution of the elements, multiple-neutrons and tiny black holes in cold fusion would correspond to the productions of white dewarves, neutron-stars and big black holes in the universe, respectively. We can say that cold fusion is a small scale simulation of the events that occur in cold stars faraway in the universe. Now we can reproduce the novels of the universe in our laboratory. Therefore, the non-baryons of the gravity decay products might be found during cold fusion, that can be expected to be dark matters.

4. 6 Summaries

In the preceding sections, the mechanisms of cold fusion have been well explained by the Nattoh model. Although important things such as the productions of ^4H and non-baryon particles remain unproven, we have comprehensively but qualitatively understood the extraordinary phenomena associated with cold fusion. It is characteristic that cold fusion burns in various manners depending on the conditions, because the hydrogen-cluster envolves many hydrogens. The branching ratios of the hydrogen-catalyzed fusion reactions are critical factors that are determined by the conditions of the electrolysis, the microscopic structure of the metals and so on. They will be studied quantitatively from now, but it seems very laborious because there are many cases. Furthermore, the study of cold fusion will be progressed towards the high voltage and current to achieve the higher efficiency of transforming mass to energy. There the gravity decays instead of the fusion reactions predominate so that new science such as black and white holes will be fully developed.

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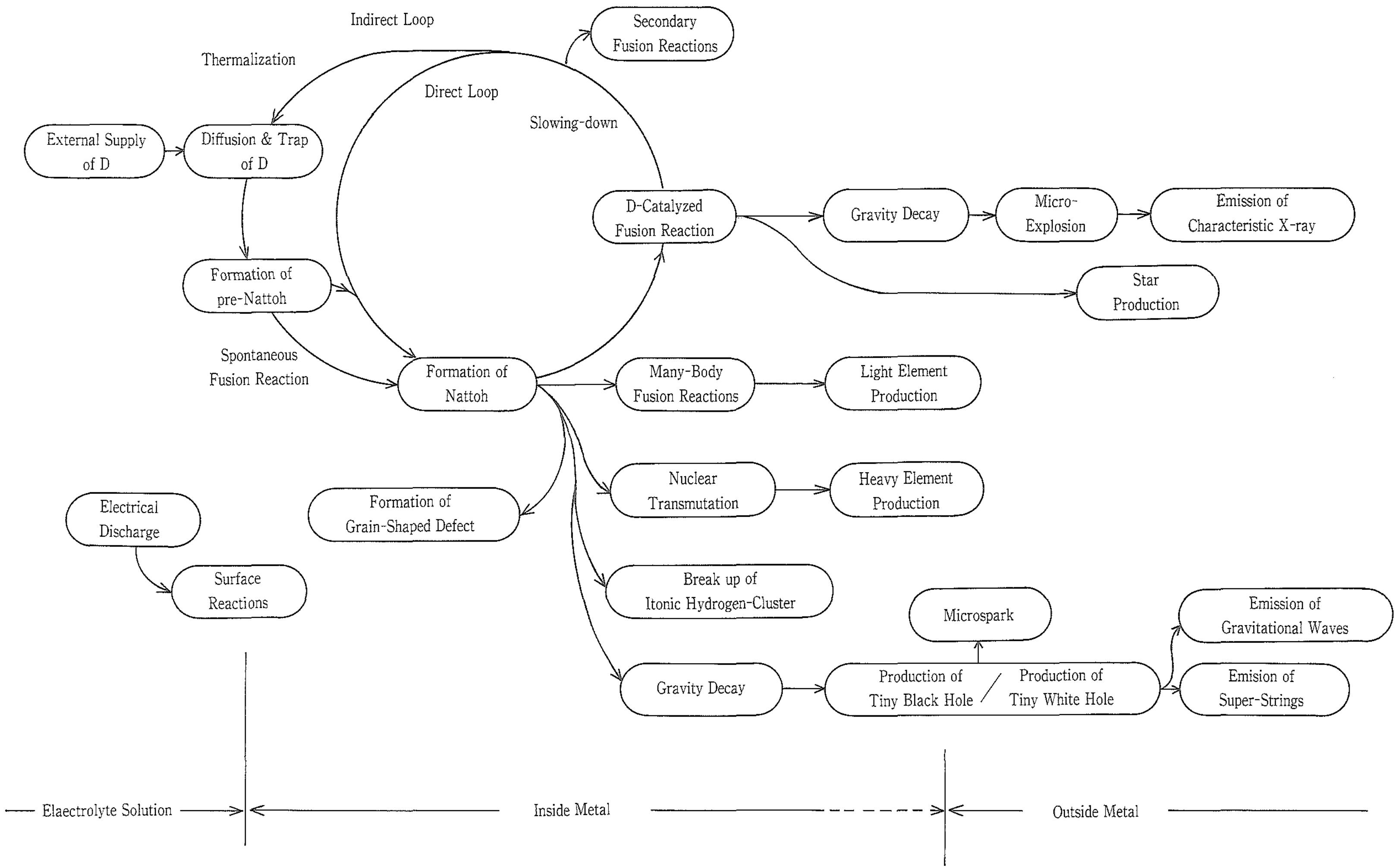

Fig. 1 : Mechanisms of cold fusion