EXCITED STATES OF NUCLEONS IN A NUCLEUS AND COLD FUSION PHENOMENON IN TRANSITION-METAL HYDRIDES AND DEUTERIDES

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Synopsis

The interaction between a neutron in a nucleus at a lattice point (in a lattice nucleus) and another neutron in a different lattice nucleus mediated by a proton (or deuteron) at an interstitial site is formulated. The interaction between neutrons through the interstitial protons (or deuterons) could be called *the super-nuclear interaction* for its long-range nature even if the strength may be extremely small compared with neutron-neutron interaction by the nuclear force in a nucleus. If the neutrons are in an excited state of the nucleus with a wave function with larger orbits than that of the ground state, the interaction becomes considerable to make the excited states form a rather wide band (*neutron valence band*) similar to valence bands of electrons in semiconductors. Possible influences of the super-nuclear interaction on the nuclear reactions in solids are discussed.

1. Introduction

It has been shown that thermal neutrons from ambient are trapped in a crystal with a finite extension limited by reflecting walls, which are formed at boundaries of two crystals at the surface having different nature.[1,2] Then, the energy spectrum of these neutrons forms a band structure with positive energies (a neutron conduction band).[3] These neutrons will show several characteristics relevant to the cold fusion phenomenon (CFP), i.e. nuclear reactions and accompanying events occurring in solids with high densities of hydrogen isotopes in ambient radiation.[4] First of all, neutrons with wave vectors around Brillouin zone boundaries have local coherence in a definite length (a coherence length) at the reflecting boundary.

The local coherence, then, produces a high density of neutrons in the boundary region with a finite width, of an order of the coherence length, which is determined by the structure of the dispersion relation of the band neutron; the narrower the energy band, the larger the coherence length as long as the band is an effective concept to describe the neutrons. The effective minimum band-width Δ_{min} may be given by thermal energy of the lattice kT as follows; $\Delta_{min} \sim$ kT. This relation gives a temperature effect on the state of neutrons in solids.

The expected density of neutrons in the coherence region is estimated from experimental data in CFP to be as high as 10^{30} cm^{-3}, resulting in clusters of neutrons with a few protons (neutron drops).[5] The new state of neutrons in solids discovered in these works will show various novel phenomena induced by the interaction of neutrons with lattice nuclei. One of these phenomena should be CFP.

Formation of another type of neutron energy band (neutron valence band) in a PdH (D) crystal originated from excited states of neutrons in Pd nuclei on the crystal lattice (lattice nuclei) is formulated in this paper using data in nuclear physics and in solid state physics.

2. Neutron Band formed by Interaction between Neutrons through Interstitial Protons

The nuclear structure of isolated nuclei in the energy region up to several hundred MeV has been thoroughly investigated in about ninety years to accomplish its fundamental understanding in the energy region up to several hundred MeV[6,7] after the discovery of the atomic nucleus in 1911. The global features of the energy levels of nucleons and their distribution seem to be fairly well described by the Fermi-gas model,[6] even if they are mainly confined to light nuclei, and a quantitative analysis is plagued with difficulties in the description of the reaction mechanism. It is interesting, therefore, to investigate excited levels with energies very close to the zero level; which corresponds to the neutron level with a binding energy of zero in the nucleus ${}^{A}_{Z}$X, or to the state where a neutron and the separated nucleus ${}^{A-1}_{Z}$X remain still. (We use this energy standard in this paper unless otherwise stated.) Therefore, it is interesting to have some phenomena which are directly related with the highest excited levels of nucleons in medium and heavy nuclei.

It is a common knowledge in nuclear physics that average properties of the excitation spectrum of nucleons in a nucleus are given by the Fermi-gas model as a result of dominance of the particle degrees of freedom over the number of collective modes.[6]

In the Fermi-gas model, nucleons in a lattice nucleus at $\boldsymbol{a}_i$ is treated as independent particles and their quantum states $\psi_{\{n\}}(\boldsymbol{r}-\boldsymbol{a}_i)$ are specified by quantum numbers $\{n\} \equiv (n, \ell, m)$ omitting spin parts for simplicity;[8)]

$$\psi_{\{n\}}(\vec{r}-\vec{a}_i) \equiv \psi_{nlm}(\vec{r}-\vec{a}_i). \tag{1}$$

The wave function of a neutron in a nucleus ^A_ZX, however, extends far away from the nucleus when the energy E of the state is less than but close to zero and then the wave function outsides the nucleus is approximated by

$$\psi_{\eta,\ell,m}(\vec{r}-\vec{a}_i) = c_i e^{-\eta|\vec{r}-\vec{a}_i|} Y_{\ell,m}(\theta_i, \phi_i), \tag{2}$$

where $\eta \equiv \eta(|E|)$ is a damping factor of the radial wave function depending on the energy but assumed for simplicity to be independent of quantum numbers, and (θ_i, ϕ_i) are angles measured from the lattice point $\boldsymbol{a}_i$. In the following treatment, we use the wave function (1) until we need the wave function (2).

The result of the calculation of the total level density for the Fermi gas is given as;[6)]

$$\rho(N, Z, \varepsilon) = \frac{6^{1/4}}{12} \frac{g_0}{(g_0\varepsilon)^{5/4}} \exp\{2(\frac{\pi^2}{6} g_0\varepsilon)^{1/2}\} \quad (N \approx Z), \tag{3}$$

where ε is the excitation energy measured in relation with the ground state and g_0 is the one-particle level density at the Fermi energy ε_F representing the sum of the proton and neutron level densities:

$$g_0 \equiv g(\varepsilon_F) = \frac{3}{2}\frac{A}{\varepsilon_F}, \tag{4}$$

for a case $Z = N = A/2$.

The energy range where the above formula is applicable is determined by a relation

$$\frac{\varepsilon_F}{A} \ll \varepsilon \ll \varepsilon_F A^{1/3}, \tag{5}$$

where $\varepsilon_F \leq 37$ MeV for heavy nuclei. This relation gives an energy range of applicability $0.4 \sim 170$ MeV for nuclei with mass numbers $A \sim 100$.

High density of nuclear levels at high excitation energies, amounts of the order 10^6 times higher than that corresponding to single-particle motion, has been revealed by densely spaced, sharp resonance in the slow neutron capture reactions in a nucleus with $A \sim 100$.[6)] The figure 10^6 will be increased further by several orders when the energy of the slow neutron capture reactions goes down to ~ 1 eV. In the following discussion, we will take this factor as 10^9 at its maximum suggested by experimental data for Ag in the range of 2 to 8 MeV[9)] considering later application to Pd isotopes in the energy range up to 10 MeV.

3. Effective Potential for the Super-nuclear Interaction between Neutrons in Adjacent Lattice Nuclei of Transition-Metal Hydrides and Deuterides

The nuclei of the transition-metal element on the lattice points (lattice nuclei) have six hydrogen isotope nuclei (protons or deuterons) as nearest neighbors at interstices half lattice constant 1.95 Å apart. The proton (deuteron) at an interstice is described as a three-dimensional harmonic oscillator in its ground and lower excited states[10,11)] and is sometimes described by proton (deuteron) Bloch waves in its excited states.[12)] The wave function of a proton (deuteron) in a state specified by quantum numbers $\{p\} \equiv (n_p, \ell, m)$ at an interstice $\boldsymbol{b}_j$, $\varphi_{\{p\}}(\boldsymbol{R}-\boldsymbol{b}_j)$ has finite probability density at nearby lattice nuclei especially when it is in excited states.[13)] If we ignore mutual interaction of protons (deuterons) in different interstices, the total proton (deuteron) wave function may be expressed as a product of wave functions on the interstices as follows with $\{p_\alpha\} = (p_1, p_2, \cdots p_Z)$;

$$\Phi_{\{p_\alpha\}}(\vec{R}_1, \vec{R}_2, \cdots \vec{R}_Z) = \prod_j \varphi_{\{p_j\}}(\vec{R}_j - \vec{b}_j). \tag{6}$$

The overlapping of the proton (deuteron) wave function $\varphi_{\{p\}}(\boldsymbol{R}_j - \boldsymbol{b}_j)$ on the interstice $\boldsymbol{b}_j$ with a nucleon (neutron) wave function $\psi_{\{n\}}(\boldsymbol{r}-\boldsymbol{a}_i)$ of an adjacent lattice nucleus at $\boldsymbol{a}_i$ results in the proton (deuteron)-neutron interaction through the nuclear force.

The nuclear force is expressed by the gradient of a potential $V(\boldsymbol{r}-\boldsymbol{R}_j)$ whose form is taken as:[14)]

$$\begin{aligned} V_{sw}(\vec{r}-\vec{R}) &= -V_0^{(s)}, \quad (|\vec{r}-\vec{R}| < b) \\ &= 0, \quad (|\vec{r}-\vec{R}| > b) \quad \text{(Square well)}, \end{aligned} \tag{7}$$

where $V_0^{(s)} \sim 3.5$ MeV.[12]

This interaction brings two nucleons (neutrons) in lattice nuclei on different lattice points in coupling with each other which we named the super-nuclear interaction as explained in Introduction. In the following investigation, we concentrate on neutrons in lattice nuclei than protons which are in lower levels in the ground state due to the general rule $Z < N$ and need more energy for excitation to levels around zero.

To investigate properties of the super-nuclear interaction between neutrons in different nuclei, we use the tight-binding approximation for excited neutrons in lattice nuclei. In a periodic potential of lattice nuclei, a neutron in an excited level of a lattice nucleus is described quantum mechanically as a linear combination of states centered at each lattice nucleus with the same probability and its state is expressed by a Bloch function;[15]

$$\psi_{\vec{k}\{n\}}(\vec{r}) = \sum_i e^{i(\vec{k}\vec{a}_i)}\psi_{\{n\}}(\vec{r} - \vec{a}_i). \tag{8}$$

Therefore, the total wave function of a system composed of a neutron Bloch wave and Z protons at interstices is expressed as follows (neglecting spin parts of wave functions, for simplicity);

$$\Psi_{\vec{k}\{n\},\{p_\alpha\}}(\vec{r}; \vec{R}_1, \vec{R}_2, \cdots \vec{R}_Z) = \psi_{\vec{k}\{n\}}(\vec{r})\Phi_{\{p_\alpha\}}(\vec{R}_1, \vec{R}_2, \cdots \vec{R}_Z), \tag{9}$$

The description of neutrons by the Bloch functions becomes a good approximation when the band width finally obtained is wide enough to make the neutrons move freely in the crystal not disturbed by perturbations causing aperiodicity in the periodic potential of the lattice nuclei. The origin of the perturbation will be lattice imperfections (caused by deviation from PdH (D) composition), thermal oscillation of the lattice nuclei, impurity atoms, and so on.

The neutrons in excited states of lattice nuclei and occluded protons (deuterons) at interstices could be treated independently because an exchange of the neutron and the proton results in fairly high-energy states and does not occur with high probability. The total energy $E_{\vec{k},\{p_\alpha\}}$ of the system with a neutron in a band state k and protons in states $\{p_\alpha\}$ in this approximation is expressed as follows in the second-order perturbation calculation taking the square-well potential (7) for the nuclear potential:

$$\begin{aligned}
E_{\vec{k}\{n\},\{p_\alpha\}} &= E_{\{n,p_\alpha\}} + \sum_{k',i,i',j} \exp(-i(\vec{k}\vec{a}_i - \vec{k}'\vec{a}_{i'}))v_{np}(ii'j), && (10)\\
v_{np}(ii'j) &= \sum_{\{n'\},\{p'\}\neq\{n\},\{p\}} \frac{< np; ij|V|n'p'; ij >< n'p'; i'j|V|np; i'j >}{E_{\{n',p'\}} - E_{\{n,p\}}} \\
&= \sum_{\{p'\}\neq\{p\}} P\int_{-\infty}^{\infty} \mathrm{d}E\rho_n(E)\frac{< np; ij|V|n'p'; ij >< n'p'; i'j|V|np; i'j >}{E + \varepsilon_{p'p}}, && (11)\\
E_{\{n,p_\alpha\}} &= E_{\{n\}}^{(p)} + \sum_j \varepsilon_{p_j}, && (12)\\
V(\vec{r}) &= V_s(\vec{r}), && (13)\\
< np; ij|V|n'p'; ij > &= \int\int \mathrm{d}\vec{r}\mathrm{d}\vec{R}_j \psi^*_{\{n\}}(\vec{r} - \vec{a}_i)\varphi^*_p(\vec{R}_j - \vec{b}_j) \\
&\quad \times V(\vec{r} - \vec{R}_j)\psi_{\{n'\}}(\vec{r} - \vec{a}_i)\varphi_{p'}(\vec{R}_j - \vec{b}_j), && (14)
\end{aligned}$$

where ρ_n(E) is the level density of excited states for a neutron, $\varepsilon_{p'p} \simeq \varepsilon_{p'} - \varepsilon_p$, and $E \simeq E_{\{n'\}} - E_{\{n\}}$, summations over i and i' are only over the nearest neighbor lattice points $\boldsymbol{a}_i$ and $\boldsymbol{a}_{i'}$ of the interstice $\boldsymbol{b}_j$, summations over $\{n', p'\}$ exclude the term where the denominator becomes zero, $E^{(p)}_{\{n\}}$ is an energy of a neutron in an excited state $\psi_{\{n\}}(\boldsymbol{r}-\boldsymbol{a}_i)$ in a lattice nucleus at $\boldsymbol{a}_i$ when protons are in states $\{p_\alpha\}$, and ε_{p_j} is an energy of a proton in a state $\varphi_{p_j}(\boldsymbol{R}_j - \boldsymbol{b}_j)$ at an interstice $\boldsymbol{b}_j$. The neutron energy $E^{(p)}_{\{n\}}$ can be approximated by the energy of a neutron in a lattice nucleus interacting with protons in a state $\bar{p}$, an average of p_i's because $|E_n| \gg |\varepsilon_p|$. We ignore, however, p-dependence of $E^{(p)}_{\{n\}}$ hereafter in this work ($E^{(p)}_{\{n\}} = E_{\{n\}}$).

To specify the neutron wave functions $\psi_{\{n\}}(\boldsymbol{r}-\boldsymbol{a}_i)$ to calculate matrix elements in the above equation, we utilize knowledge obtained in the shell model calculation. We use the Fermi-gas model with the nuclear harmonic oscillator potential. Then, the wave functions and energy eigenvalues specified by quantum numbers (n,ℓ,m) are written down as follows;[12]

$$\psi_{n\ell m}(r,\theta,\phi) = R_{n\ell}(r)Y_{\ell m}(\theta,\phi), \quad (|m| \le \ell) \tag{15}$$

$$E_{\{n\}} \equiv E_{n\ell m} = (n+\frac{3}{2})\hbar\omega_n + \Delta\varepsilon_{\ell m}, \tag{16}$$

where $\Delta\varepsilon_{\ell m}$ expresses the $l \cdot s$ and other coupling energies taken symbolically into consideration to distinguish energies of the states with the same n and different ℓ, m, ω_n is the circular frequency of the nuclear harmonic oscillator and $Y_{\ell,m}(\theta,\phi)$ are the spherical harmonics.

A concrete expression of one of the matrix elements (14) for PdH is expressed using wave functions of the occluded protons at interstices and excited neutrons in a lattice nucleus as follows;

$$\begin{aligned} & < 2f_{7/2}1d; ij|V|3p_{3/2}2s; ij > \\ = & -\int\int \mathrm{d}\vec{r}\mathrm{d}\vec{R}_j R_{53}(z_i)Y_{3,0}(\theta_i,\phi_i)\xi_{1d}(Z_j)Y_{2,0}(\Theta_j,\Phi_j) \\ & \times V_{sw}(\vec{r}-\vec{R}_j)R_{51}(z_i)Y_{1,0}(\theta_i,\phi_i)\xi_{2s}(Z_j)Y_{0,0}(\Theta_j,\Phi_j), \\ z_i = & \ 2\alpha_n|\vec{r}-\vec{a}_i|^2, \quad Z_j = 2\alpha_p|\vec{R}_j-\vec{b}_j|^2, \end{aligned} \tag{17}$$

where $\boldsymbol{a}_i$ is a nearest neighbor lattice site of the interstice $\boldsymbol{b}_j$, K in α_p is K_H given in the reference,[13] and (θ_i,ϕ_i) and (Θ_j,Φ_j) are angles measured from origins at $\boldsymbol{a}_i$ and $\boldsymbol{b}_j$, respectively.

Because the triton is much more tightly bound than the deuteron, the potential $V_{sw}^{(nd)}(\boldsymbol{r}-\boldsymbol{R})$ for a deuteron in PdD system should be deeper than $V_{sw}(\boldsymbol{r}-\boldsymbol{R})$ in (17). For a qualitative calculation of the matrix element (17) with $V_{sw}^{(nd)}(\boldsymbol{r}-\boldsymbol{R})$, we may use a following form for the potnetial;

$$V_{sw}^{(nd)}(\vec{r}-\vec{R}) = \xi V_{sw}(\vec{r}-\vec{R}), \tag{18}$$

where ξ is a numerical factor of an order of the ratio of binding energies of triton (8.5 MeV) and deuteron (2.2 MeV) reduced to per a nucleon; $\xi \sim (8.5 \div 3)/(2.2 \div 2) \sim 2.6$.

The order of magnitude of the effective potential energy v_{np}(ii'j) for PdH, however, is roughly estimated as follows: the proton wave function ϕ_p(R) is slowly varying in the range of the nuclear force, and the nuclear wave function $\psi_{\{n\}}(\boldsymbol{r})$ is approximated by a delta-function. Then, an order of magnitude of the matrix elements $< np; ij|V|n'p'; ij >$ is given as

$$|< np; ij|V|n'p'; ij >| \sim \int \psi_n^*\psi_n \mathrm{d}\vec{r} < V > \phi_p^*\phi_p\Omega \tag{19}$$

$$\begin{aligned} & \sim 1 \times \frac{4}{3}\pi r_0^3 \times |u_2(x_N)|^2|u_0(0)|^2|u_0(0)|^2 \\ & = 3.2 \times 10^{-14} \quad \mathrm{eV}, \end{aligned} \tag{20}$$

where Ω is the volume of the Pd nucleus, $< V > \simeq |V_0^{(s)}| \simeq 3.5$ MeV (Eq.(7)), $\varphi_p(\boldsymbol{R})$ is taken as $u_2(x)u_0(y)u_0(z)$ and $x_N \simeq 1.95$ Å is the position of the lattice nucleus measured from the interstice.

Putting this value (20) into Eq.(11), we can estimate the effective potential energy $v_{np}(ii'j)$ as a function of the principal value of the integration appeared in that equation, assuming the insensitiveness of the matrix elements to the energy:

$$\begin{aligned} v_{np}(ii'j) & \sim 1 \times 10^{-27}(\mathrm{eV}^2)I, \\ I & \equiv P\int \frac{\rho_n(E)}{E}\mathrm{d}E. \end{aligned} \tag{21}$$

We can, then, estimate the approximate value of the integral I, taking following values $\rho_n(E) \sim 10^9$ keV^{-1}, $\delta\varepsilon \sim 10^{-9}$ keV, and $\Delta\varepsilon \sim 1$ keV on the assumption that single particle energy level difference is ~ 1 keV and the level density increases to 10^9 times larger than that of single particle motion:

$$I \sim \frac{\rho_n(\varepsilon)}{\delta\varepsilon}\Delta\varepsilon = 10^{15} \quad \mathrm{eV}^{-1}. \tag{22}$$

Thus, an order of magnitude of $v_{np}(ii'j)$ in PdH becomes

$$v_{np}(ii'j) \sim 1 \times 10^{-12}(\mathrm{eV}). \tag{23}$$

The value of $v_{np}(ii'j)$ in PdD may be taken as one order of magnitude larger than this value if we consider the factor $\xi=2.6$ ($\xi^2 = 6.8$) and $u_3(x_N)$ instead of $u_2(x_N)$ in Eq.(20).

4. Tight-Binding Neutron Bands in Transition-Metal Hydrides and Deuterides To show crystal-structure dependence of the band width, we can use a simplification of the super-nuclear interaction between adjacent nuclei assuming that it depends only on the magnitude of vectors $(\boldsymbol{a}_i - \boldsymbol{a}_{i'}) \equiv \boldsymbol{a}_i$ (taking $\boldsymbol{a}_{i'} \simeq 0$). We can, then, rewrite the neutron parts of expression (12) as follows;

$$E = E_n - \alpha - \gamma \sum_i e^{-i(\vec{k}\vec{a}_i)}, \tag{24}$$

$$-\alpha = v_{np}(iij), \tag{25}$$

$$-\gamma = v_{np}(ii'j). \tag{26}$$

Using the value of $v_{np}(ii'j)$ given in (23), we obtain a semi-quantitative estimation of the valence band width Δ from Eq.(24):

$$\Delta = 24 v_{np}(ii'j) \sim 10^{-8} \text{ (meV) (PdH)}. \tag{27}$$

Thus, it is concluded that the matrix elements (17) should be 10^5 times larger than the values estimated in (23) to substantially keep the neutron bands below zero which was determined to form in solids with a width $\Delta \geq 25$ meV that is not destroyed by the thermal motion of ions at room temperature. This is realized only when the neutron wave function (1) extends out as the wave function (2) from a lattice nucleus to regions where a wave function of the occluded proton has a larger value by a factor 10^5 than that at the lattice nuclei.

The main term of the proton wave function relevant to this behavior is the exponential factor $e^{-\frac{1}{2}\alpha^2 x^2}$ and it gives this value 10^5 at $x_0 \simeq 1.43$ Å from an interstice (or 0.52 Å from a lattice point). If this behavior is coupled with an extension of the neutron wave function (2), then the neutron-proton interaction can contribute to formation of a neutron valence band with a width of $\Delta \geq 25$ meV.

We consider here an s-type wave function for the state, for simplicity:

$$\psi_\eta(\vec{r} - \vec{a}_i) = c_i e^{-i\eta|\vec{r} - \vec{a}_i|}. \tag{28}$$

To extend the neutron wave function to the range of $\lambda = 5.2 \times 10^{-9}$ cm referred above, the decay constant of the state $\eta(|E|) \simeq 1/\lambda$ should be 1.9×10^8 cm^{-1} and this corresponds to an energy E:

$$|E| = \frac{\hbar^2}{2m_n}\eta(|E|)^2 = 7.4 \text{ (eV)} \tag{29}$$

below zero, where $m_n \simeq 1.67 \times 10^{-24}$ g is the neutron mass. In other words, the excited states of isolated lattice nuclei with energies down to 7 eV from zero can participate to *the neutron valence band*, or the neutron bands below zero, in transition-metal hydrides considered above.

If the state has less energy, i.e. far from zero, and the extension of the state is less than 5.2×10^{-9} cm, the band state fails to be substantially formed even in PdH and neutrons are essentially in single particle states in isolated lattice nuclei.

The width Δ of the neutron band (24) is $\sim 24\gamma = 24 v_{np}(ii'j)$. Putting the numerical values obtained in (23) for PdH and one for PdD by multiplying a factor of 10 to that of PdH as discussed on the end of Section 3, we obtain

$$\Delta = 10^{-8} \text{ (meV) (PdH)}, \tag{30}$$

$$\Delta = 10^{-7} \text{ (meV) (PdD)}. \tag{31}$$

Thus, these neutron states pulled down to just below zero from free states above zero by attractive interaction with lattice nuclei or excited states of lattice nuclei close to zero energy can be candidates of those states participating the neutron valence bands below zero in transition-metal hydrides considered above.

5. Discussion

First of all, it should be kept in mind following facts about anomalous nuclear reactions in solids. The cold fusion phenomenon (CFP) is most frequently observed in transition-metal deuterides and hydrides, especially in TiD (H), NiH (D), and PdD (H). Furthermore, these transition-metal nuclei have a common characteristic; existence of excited neutron levels near zero in an isolated nucleus, $1f_{5/2}$ in Ti, $3s_{1/2}$ in Ni, and $2f_{7/2}$ in Pd.[6] Therefore, the investigations on PdH (D) given in the preceding sections are straightforwardly applicable to such materials as TiD (H), NiH (D), and others with necessary modifications to meet characteristics of each material.

When there are many neutrons in a neutron band formed by characteristics of transition-metal hydrides and deuterides, there appear interesting features of neutron's behavior at boundaries that reflect neutrons back into the crystal; "local coherence" of neutron Bloch waves, and therefore, high densities of neutrons appear there[4]. High-density neutrons in the boundary region[5] or in neutron star matters[16] induce formation of "neutron drops" (or clusters of many neutrons and a few protons) in a thin neutron background. These neutron drops in a thin neutron background interact with nuclei to produce new nuclear effects in the boundary region.

The difference of Δ of PdH and PdD given in Eqs.(30) and (31) tells us the latter is advantageous to realize CFP if other conditions are the same. This result seems in accordenace with experience obtained in a decade of CF research.

Finally, we would like to notice a new point of view; it should be considered that various events in CFP are results of measurements using various probes to look into physics of a complex system composed of transition metals and hydrogen isotopes occluded in them in ambient radiations. If we do not confine our investigation in a narrow scheme presupposed by a biased viewpoint, new perspective can be developed on the basis suggested by experimental facts, even if they seem too complicated at first sight to be treated consistently.

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