"The Coulomb Barrier not Static in QED" A correction to the Theory by Preparata on the Phenomenon of Cold Fusion and Theoretical Hypothesis

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Abstract

In the last two decades, irrefutable experimental evidence has shown that Low Energy Nuclear Reactions (LENR) occur in specialized heavy hydrogen systems [1-4]. Nevertheless, we are still confronted with a problem: the theoretical basis of LENR are not known and, as a matter of fact, little research has been carried out on this subject. In this work we seek to analyse the deuteron-deuteron reactions within palladium lattice by means of Preparata's model of the palladium lattice [5,15]. We will also show the occurrence probability of fusion phenomena according to more accurate experiments [6]. We are not going to use any of the research models which have been previously followed in this field. Our aim is to demonstrate the theoretical possibility of cold fusion. Moreover, we will focus on tunneling the existent Coulomb barrier between two deuterons. Analysing the possible contributions of the lattice to the improvement of the tunneling probability, we find that there is a real mechanism through which this probability could be increased: this mechanism is the screening effect due to d-shell electrons of palladium lattice. The accordance between theoretical and experimental results will prove the reality of cold fusion phenomena and show the reliability of our model.

1. Introduction

Our research has shown that cold fusion phenomena were verified by the Coherence Theory of Condensed Matter. In this theory [5] it is assumed that the electromagnetic (e.m.) field plays a very important role on dynamic system, due to elementary constituents of matter (i.e. ions and electrons). Due to charged matter, considering the coupling between e.m. equations and the Schrödinger equation of field matter operator, it is possible to demonstrate that the matter system shows a dynamic coherence in proximity of e.m. frequency ω_{0}.. Hence, it is possible to define the coherence domains, whose length is about $\lambda_{CD} = 2\pi/\omega_0$.

The simplest model of matter with coherence domain is obviously the plasma system. In classical plasma theory we have to consider the plasma frequency ω_p and the Debey length that measures the Coulomb force extension, i.e. the coherence domain length. In order to address the crucial issue of the nuclear fusion reaction involving the deuterons that pack the Pd-lattice, we must have a rather detailed understanding of the environment in which such nuclear process will eventually take place.

For a system with N charge Q of m mass within a V volume the plasma frequency can be written as:

$$\omega_{\vec{k}} = \omega_p = \frac{Qe}{\sqrt{m}}\sqrt{\frac{N}{V}} \tag{1}$$

Introducing the dimensional variable $\tau = \omega_p t$ we can rewrite the above equations as follows:

$$\dot{\phi}_{\vec{n}}(\tau) = \frac{1}{2}\sum_{|\vec{k}|=\omega_p}\sum_{\vec{n}'r}\langle \vec{n}|\alpha_{kr}\vec{\varepsilon}_{kr}\vec{a}^{+} - \alpha^{*}_{kr}\vec{\varepsilon}_{kr}\vec{a}|\vec{n}'\rangle\phi_{\vec{n}'}(\tau) \tag{2}$$

$$\frac{1}{2}\ddot{\alpha}_{kr} - i\dot{\alpha}_{kr} + m\lambda\alpha_{kr} = \frac{i}{2}\vec{\varepsilon}^{*}_{kr}\sum_{\vec{n}\vec{n}'}\langle \vec{n}|\vec{a}|\vec{n}'\rangle\phi^{*}_{\vec{n}}(t)\phi_{\vec{n}'}(\tau) \tag{3}$$

Defining the state as:

$$|\phi\rangle = \sum_{\vec{n}'}\phi_{\vec{n}}(\tau)|\vec{n}\rangle \tag{4}$$

and the e.m. field amplitude as:

$$\vec{A} = \sqrt{\frac{3}{8\pi}}\sum_{r}\int d\Omega_k\alpha_{kr}\vec{\varepsilon}_{kr} \tag{5}$$

we can rewrite as follows:

$$\frac{\partial}{\partial t}|\phi\rangle = \sqrt{\frac{2\pi}{3}}\left(\vec{A}\vec{a}^{+} - \vec{A}^{+}\vec{a}\right)|\phi\rangle \tag{6}$$

$$\dot{\vec{A}} + \frac{i}{2}\ddot{\vec{A}} + im\lambda\vec{A} = -\sqrt{\frac{2\pi}{3}}\langle\phi|\vec{a}|\phi\rangle \tag{7}$$

If we only concentrate on a short time dynamics, we can write:

$$|\phi(0)\rangle = |0\rangle \tag{8}$$

then, creating a difference in the (6) and using the (7) with $|\phi\rangle = |0\rangle$, we can easily obtain:

$$\ddot{A}_j + \frac{i}{2}\dddot{A}_j = -\left(\frac{2\pi}{3}\right)\langle 0|\left[a_j, a_l^{+}\right]|0\rangle \tag{9}$$

$$A_l = -\left(\frac{2\pi}{3}\right)A_j \tag{10}$$

This has the same form of the equations of the coherence domains as the case in which:

$$\mu = 0$$

$$\lambda = 0$$

$$g^2 = \left(\frac{2\pi}{3}\right)$$

$$g_c^2 = \frac{16}{27} < \frac{2\pi}{3}$$

So, a solution for the ideal plasma exists. More in detail, we can define:

$$\alpha_k = \langle \phi | a_k | \phi \rangle \tag{11}$$

$$g_0 = \left(\frac{2\pi}{3} \right)^{1/2}$$

In this case the coupling critical constant is:

$$\dot{\alpha}_k = g_0 A_k \tag{12}$$

$$\dot{A}_k + \frac{i}{2} \ddot{A}_k = -g_0 \alpha_k \tag{13}$$

so to admit the following holding quantity:

$$Q = \sum \left\{ A_k^* A_k + \frac{i}{2} \left(A_k^* \dot{A}_k - \dot{A}_k^* A_k \right) + \alpha_k^* \alpha_k \right\} \tag{14}$$

while for the Hamiltonian's it is easy to compute:

$$\frac{E}{N\omega_p} = H = Q + \sum \left[\frac{1}{2} \dot{A}_k^* \dot{A}_k - ig \left(A_k^* \alpha_k - A_k \alpha_k^* \right) \right] \tag{15}$$

With the aim of seeing if there are any externals solutions, we write

$$\alpha_k = \alpha u_k e^{i\psi} \tag{16}$$

$$A_k = A u_k e^{i\phi} \tag{17}$$

where α and A are positive constants and u_k is a complex vector.

Changing these ones in (12) and (13) we have:

$$\phi - \psi = \frac{\pi}{2} \tag{18}$$

$$\alpha = g_0 \frac{A}{\dot{\phi}} \tag{19}$$

$$\frac{1}{2} \dot{\phi}^3 - \dot{\phi}^2 + g_0^2 = 0 \tag{20}$$

and by the condition *Q=0* (we cannot have a net charge flow in a plasma), we have:

$$1 - \dot{\phi} + \frac{g_0^2}{\dot{\phi}^2} = 0 \tag{21}$$

In this case it is easy to observe that for $g_0 = \left(\frac{2\pi}{3} \right)^{1/2}$ it is unlikely that both the equations (18) and (19) are satisfied.

This result means that the energy of an ideal quantum plasma does not have a minimum; in other words, an ideal quantum plasma does not exist.

That must not be surprising, because the Hamiltonian' describes this plasma as a system whose amplitude oscillations are arbitrary, whereas the limit over a certain amplitude does not exist in a real plasma.

But by:

$$\vec{\xi} = \frac{1}{\sqrt{2m\omega_p}}(\vec{a} + \vec{a}^+)$$

it is easy to obtain:

$$\left\langle \vec{\xi}^2 \right\rangle = \frac{1}{m\omega_p}\alpha^2 \tag{22}$$

Also, in the plasma approximation as an homogeneous fluid, we suppose that our Hamiltonian's stops have to be valid for the oscillations bigger than the following:

$$\left\langle \vec{\xi}^{\,2} \right\rangle_{\max}^{1/2} \approx a = \left(\frac{V}{N}\right)^{1/2} \tag{23}$$

that is when plasma oscillations are of the same order as the inter-particle distance *a*. In order to create some more realistic models of plasma, we want to compute the breaking amplitude α_{max} obtained by the combination of the equations (22) and (23) for a gas of electrons.

Using the definition of ω_p, we have:

$$\alpha_{\max} = \sqrt{m\omega_p} \cdot \left(\frac{1}{3}\right)^{1/3} = (ma)^{1/4} e^{1/2} \tag{24}$$

taking

$$a \approx 2.5\text{Å}$$

the result is

$$\alpha_{\max} \cong 2.7\ \text{Å}$$

This simple calculation shows how it is possible to change our quantum ideal plasma in a real plasma. As the oscillations remain very low in a plasma, a two level model can be a good approximation (the dynamics only includes the first excited state). A consequence of this approximation consisting in the reduction of the plasma in a homogeneous fluid is the changing of the plasma frequency ω_p as follows:

$$\omega_p = \frac{Q}{\sqrt{m}}\sqrt{\frac{N}{V}} \tag{25}$$

Moreover, we study the "nuclear environment" that is supposed existent within the palladium lattice D_2-loaded and at room temperature as predicted by the Coherence Theory. As a matter of fact, some physicists declared that it is possible to observe traces of nuclear reactions [1,2,3] when the palladium lattice is loaded with deuterium gas. For this reason many of these physicists define that as a Low Energy Nuclear Reaction (LENR).

One of the most interesting experiments shows that in the D_2-loaded palladium case the most frequent nuclear reactions are:

1) $D + D \rightarrow {}^3H + p + 4.03 MeV$
2) $D + D \rightarrow {}^4H + p + 23.85 MeV$

The aim of our work is to propose a "coherence" model, by means of which we can explain the occurrence of reactions 1) and 2) and their probability according to more reliable experiments. First of all, we will start from the analysis of the environment, i.e. of plasmas present within palladium (*d*-electron, *s*-electron, *Pd*-ions and *D*-ions); we will do so using the coherence theory of matter. Then, we will use the effective potential reported in ref. [7,8] and add the role of lattice perturbations, by means of which we will compute the *D-D* tunneling probability.

2. The plasmas within non loaded palladium

According to the Coherence Theory of Condensed Matter, in a palladium crystal at room temperature the electron shells are in a coherent regime within a coherent domain. In point of fact, they oscillate in tune with a coherent e.m. field trapped in coherent domains.

So, in order to describe the lattice environment we must study the plasma of *s*-electron and *d*-electron.

a) The plasma of d-electrons

Similar arguments were proposed by Preparata, but starting from a new formulation of condensed matter theory known as Coherence Theory.

In this theory we can visualize the plasma formed by d-shell electrons as consisting of shells charged $n_d e$ (for palladium $n_d = 10$) radius $r_d = 1$ *Å* and thickness a fraction of one Angstrom. The classical plasma

$$\omega_d = \frac{e}{\sqrt{m}}\sqrt{\frac{n_d N}{V}} \qquad (26)$$

is d-electrons plasma frequency. But according to the coherence theory of matter we must adjust this plasma frequency of a factor *1.38*.

We can understand this correction by observing that the formula (26) is obtained assuming a uniform *d*-electron charge distribution. But of course the *d*-electron plasma is localized in a shell of radius *R* (that is about 1Å), so the geometrical contribution is:

$$\sqrt{\frac{6}{\pi}} = 1.38 \qquad (27)$$

If we rewrite the renormalized d-electron plasma frequency with ω_d, we have

$$\omega_d = 41.5eV/\hbar \tag{28}$$

and the maximum oscillation amplitude ξ_d is about 0.5 Å.

b) The plasma of delocalized s-electrons

The *s*-electrons are those neutralizing the absorbed deuterons ions in the lattice. They are delocalised and their plasma frequency depends on the loading ratio (*D/Pd* percentage). The formula (28) can also be written as:

$$\omega_{se} = \frac{e}{\sqrt{m}}\sqrt{\frac{N}{V}} \cdot \sqrt{\frac{x}{\lambda_a}} \tag{29}$$

where

$$\lambda_a = \left[1 - \frac{N}{V}V_{pd}\right] \tag{30}$$

and V_{pd} is the volume effectively occupied by the Pd-atom. As reported in reference [5], we obtain:

$$\omega_{se} \approx x^{1/2} 15.2eV/\hbar \tag{31}$$

As an example, for *x=0.5*, we have $\omega_{se} \sim 10.7\ eV/\hbar$.

c)The plasma of Pd-ions

Furthermore, we can consider the plasma according to the palladium ions forming the lattice structure; in this case it is possible to demonstrate that the frequency is (28):

$$\omega_{pd} = 0.1eV \tag{32}$$

3. The plasmas within D_2-loaded palladium

In this section we seek to show what happens when the absorbed deuterium is placed near the palladium surface. This loading can be enhanced using electrolytic cells or vacuum chambers working at opportune pressure [9, 10]. By means of Preparata's theory of Condensed Matter, it is assumed that there are three phases concerning the D_2-Pd system, according to the ratio *x=D/Pd*:

1) phase α for $x<0.1$
2) phase β for $0.1<x<0.7$
3) phase γ for $x > 0.7$

In the α – phase, the D_2 is in a disordered and not coherent state (D_2 is not charged).

As far as the other two phases are concerned, we can conclude that the following reaction takes place on the surface because of the lattice e.m.:

$$D_{lattice} \rightarrow D^+ + e^- \tag{33}$$

Then, according to the loading quantity *x=D/Pd,* the ions of deuterium can occur on the octahedrical sites (Fig. 1) or on the tetrahedral (Fig. 2) in the (1,0,0)-plane. In the coherent theory of the so called β-plasma of Preparata's the deuterons plasma are in the octahedral site and the γ-plasma are in the tetrahedral.

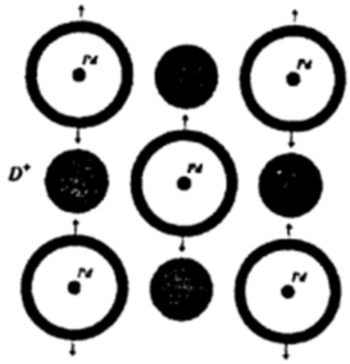

Figure 1. The octahedral sites of the Pd lattice where the deuterons are located

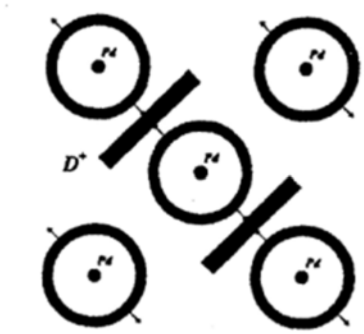

Figure 2. The thin disks of the tetrahedral sites of the Pd lattice where the deuterons are located

Regarding the β-plasma, it is possible to affirm that the plasma frequency is given by (28):

$$\omega_\beta = \omega_{\beta 0}(x+0.05)^{1/2} \tag{34}$$

where

$$\omega_{\beta 0} = \frac{e}{\sqrt{m_D}}\left(\frac{N}{V}\right)^{1/2}\frac{1}{\lambda_a^{1/2}} = \frac{0.15}{\lambda_a^{1/2}} eV/\hbar \tag{35}$$

For example, if we use $\lambda_a=0.4$ and $x=0.5$ we obtain $\omega_\beta=0.168\ eV/\hbar$.

In the tetrahedral sites the D^+ can occupy the thin disk that encompasses two sites (Fig. 3), representing a barrier to the D^+ ions. We must underline that the electrons of the *d*-shell start oscillating near the equilibrium distance y_0 (about 1.4 Å), so that the static ions have a cloud of negative charge (see reference [5]).

What follows is:

$$\omega_\gamma = \sqrt{\frac{4Z_{eff}\alpha}{m_D y_0^2}} \approx 0.65 eV/\hbar \tag{36}$$

Of course, this frequency also depends on the chemical condition of the palladium (impurities, temperature etc…)

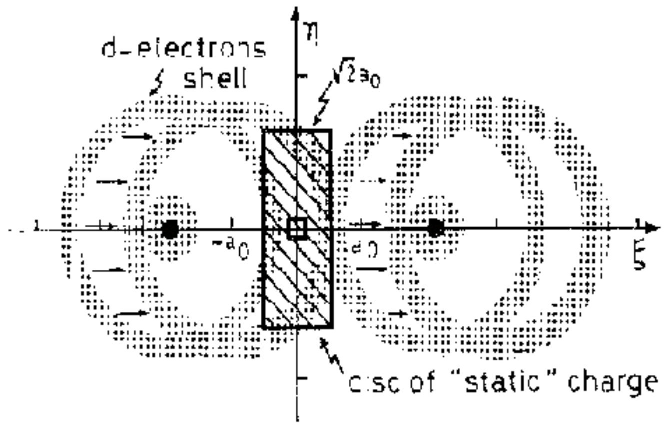

Figure 3. Possible d-electron plasma oscillation in a Pd lattice

Due to a large plasma oscillation of *d*-electrons, a high density negative charge condenses in the disk-like tetrahedral region, where the γ-phase D^+'s are located. This gives rise to a screening potential *W(t)*, whose profile is reported in Fig. 4.

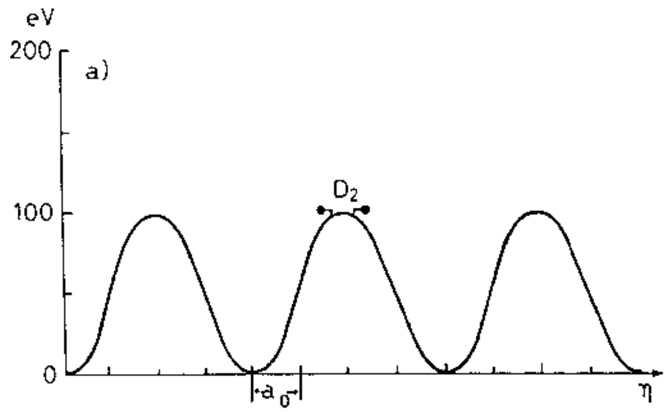

Figure 4. The profile of the electrostatic potential in the η-direction

Having mapped that the γ-phase depends on x value, we can experimentally observe the new phase in reference [11], which is very important in the LENR investigation. This is demonstrated by the fact that many of the "cold fusion physicists" declare that the main point of cold fusion protocol is the loading *D/Pd* ratio higher than *0.7*, i.e. the deuterium takes place in the tetrahedral sites.

4. The D-D potential

In reference [7], it was shown that the phenomenon of fusion between nuclei of deuterium in the lattice of a metal is conditioned by the structural characteristics, by the dynamic conditions of the system and also by the concentration of impurities that are present in the metal under examination.

In fact, the height of the Coulomb barrier decreases according to the varying of the total energy and of the concentration of impurities that are present in the metal itself. This can be observed studying the curves of the potential of interaction between deuterons (including the deuteron-plasmon contribution) in the case of three typical metals (*Pd, Pt* and *Ti*), as shown in a three-dimensional model.

The initial potential that connects the like-Morse attraction and the like-Coulomb repulsion can be written as seen in reference [7, 8]:

$$V(r) = \mathrm{k}_0 \frac{q^2}{r} \cdot \left(V(r)_M - \frac{\Sigma}{r} \right) \tag{37}$$

where $V(r)_M$ is the Morse potential, $k_0 = (1/4\pi\varepsilon_0)$, q is the charge of the deuteron, M_d is the reduced mass of the deuterium nuclei, T is the absolute temperature at which the metal is experimentally placed, J is the concentration of impurities in the crystalline lattice and R is the nuclear radius.

In (37), $V(r)_M$ is a like-Morse potential, and is given by:

$$V(r)_M = B\{\exp(-2\varphi(r-r_0)) - 2\exp(-\varphi(r-r_0))\} \tag{38}$$

Here the parameters B, φ *ed* r_0 depend on the lattice.

In fact, the potential (37) is an effective one whose reliability is demonstrated by its ability to fit the Coulomb potential for $r \rightarrow 0$ and the Morse potential in the attractive zone. So, Siclen and Jones [12] define ρ the point where the Coulomb potential is associated to the Morse trend, r'_0 the equilibrium distance and D' the well.

Of course in the free space for a D_2 molecular, ρ is about *0.3 Å* , r'_0 is about *0.7 Å* and D' is -*4.6 eV*.

But screening effects are present within the lattice, and the deuteron-deuteron interaction modify these parameter values by means of phonon exchange.

Since the screening effect [1] can be modulated by the giver atoms, in reference [7,8] we have considered the role of impurities and we came to the following: $J = J_0 \exp\left[\frac{\beta}{bkT}\right]$.

Furthermore, some particular reactions could occur, incorporating the impurities in the nucleus of the dislocations. This may happen as a result of a different arrangement of the atoms, with respect to that of the unperturbed lattice.

This type of process has been extensively studied in the literature concerning metals and the case of crystalline semiconductors at high temperature.

As an example, in the case of crystalline semiconductors it has been found that the concentration of interstitial impurities around a linear dislocation with a point component depends on the temperature, as shown by the law written above where J_0 is the concentration of impurities in the zone with zero internal pressure, ($b^3 \simeq v_i$) is the volume of the ions constituting the lattice, while β is proportional to the difference ($v_d - v_i$) between the volume of the impurity atoms and that of the lattice ions.

Our conjecture is that in a metal, such as palladium, a similar phenomenon could occur between the atoms of deuterium penetrating the lattice. This would be a result of the deuterium loading and of the microcracks produced by variations in temperature. In this case, the parameter β of the previous expression would be negative, determining an increase in the concentration of deuterons in the vicinity of the micro-crack, which would then catalyse the phenomenon of fusion as:

$$\Sigma = JKTR \tag{39}$$

and

$$B = J/\zeta \tag{40}$$

So we can write the effective *d-d* potential as follows:

$$V(r) = k_0 \frac{q^2}{r} \cdot \left(V(r)_M - \frac{JKTR}{r} \right) \tag{41}$$

where $V(r)_M$ is the Morse potential, $k_0 = (1/4\pi\varepsilon_0)$, q is the charge of the deuteron, M_d is the reduced mass of the deuterium nuclei, T is the absolute temperature at which the metal is experimentally placed, J is the concentration of impurities in the crystalline lattice and R is the nuclear radius.

Considering the attractive force, due to the exchange of plasmons, the main contribution are as follows:

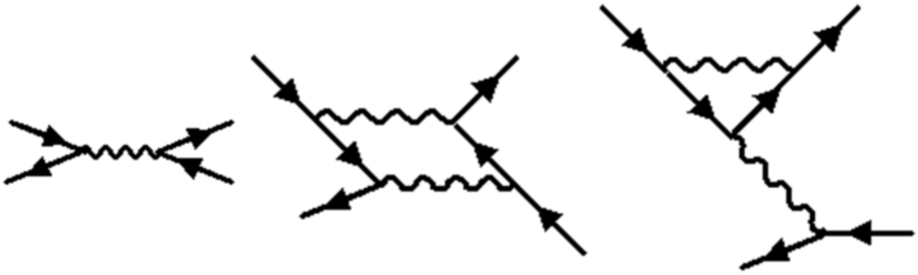

Figure 5. Plasmon exchanges. Solid lines indicate deuterons and wiggly lines indicate plasmons

Taking into account the role of coupling between deuteron and plasmons, in reference [13] a *D-D* potential was numerically evaluated, having the features of the potential (14) with *D'= -50 eV* , with $r'_0=0.5$ *Å* and with $\rho = 0.2$ *Å* (it has to be also taken into account that only two plasmon excitations at *7.5 eV* and at *26.5 eV* are considered in ref. 13).

The features of the potential (37) is shown in Fig. 6.

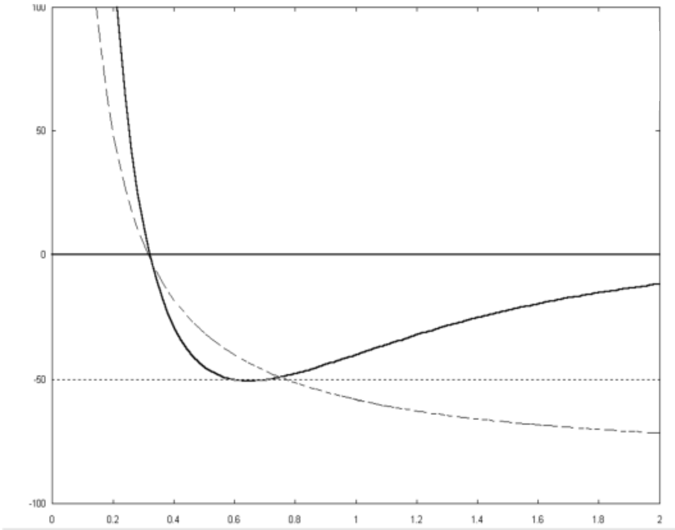

Figure 6. The solid line shows the features of potential (37) computed in order to obtain D'=-50 eV and ρ=0.165 Å. The coulomb potential in dashed line is computed using a screening constant of 85 eV. The distance in Bohr radius unit is reported on the x-axes, and the energy in eV is shown on the y-axes.

We are now going to study the role of potential (41) in the three different phases α, β and γ according to the coherence theory of condensed matter.

A couple of points require preliminary explanations before we proceed, namely:

1) what KT is;
2) what the role of plasma ions and of electrons is;

Let us start with point 1. According to the different deuteron-lattice configurations, *KT* can be:

i. the loaded lattice temperature if we consider the deuterons in the α-phase;
ii. ω_β if we consider the deuterons in β-phase;
iii. ω_γ if we consider the deuterons in the γ-phase;

The second point requires a much more complicated explanation. In fact, the lattice environment is a combination of coherent plasmas (ion Pd, electron and deuterons plasma) at different temperature, due to different masses, which makes the description of the emerging potential very difficult.

The method we propose to follow in this work is to consider the total screening contribution of lattice environment at *D-D* interaction (i.e. V_{tot}) as random potential $Q(t)$. According to this model, we have

$$V_{tot}(t) = V(r) + Q(t) \tag{42}$$

Of course, we assume that:

$$\langle Q(t) \rangle_t \neq 0 \tag{43}$$

that is to say that $Q(t)$ (a second order potential contribution) is a periodic potential that oscillates between the maximum value Q_{max} and 0. The frequency will be called by ω_Q.

More exactly, the oscillation charges of *d-shell* produce a screening potential having an harmonic feature:

$$eV(r) = -Z_d \frac{ke^2}{2a_0} r^2 \tag{44}$$

Considering $Z_d=10/3$ and $a_0= 0.7$ Å in reference [5], a screening potential V_0 is evaluated of about *85 eV*. In this way we can compute $\rho = V_0/26.9$ and at last $\rho = 0.165$ Å. Resuming, in a palladium lattice we can have the following cases according to the loading ratio:

i) α-phase

In the phase α the deuterons are in a molecular state and the thermal motion is about:

$0.02 \text{ eV} < \hbar\omega_\alpha < 0.1 \text{ eV}$

This phase takes places when x is lower than 0.1, and since $W(t)$ is zero, the D-D potential is:

$$V(r) = k\frac{q^2}{r} \cdot \left(V_M(r) - \frac{J\hbar\omega_\alpha R}{r} \right) \tag{45}$$

The expression (45) was partially evaluated in a previous paper [7]; in fact, we were only interested in the dependence of the tunneling probability on impurities present within the lattice. Through the present work, we seek to examine the correlation between potential features and loading ratio. Some numerical results are showed in the paragraph 5.

ii) β-phase

Phase β happens when *x* is higher than *0.1* but lower than *0.7*. The interaction takes place among deuteron ions that oscillate between the following energy values:

$0.1 \text{ eV} < \hbar\omega_\beta < 0.2 \text{ eV}$

In this case *W(t)* is zero, we can express the potential as follows:

$$V(r) = k\frac{q^2}{r}\cdot\left(V_M(r) - \frac{J\hbar\omega_\beta R}{r}\right) \tag{46}$$

Comparing the expressions 45 and 46, it seems clear that the weight of impurities is more important in the β-phase. Of course this conclusion relates to previous papers [7,8] in which we have studied the role of temperature on tunneling effect.

iii) γ-phase

Lastly, the deuteron-palladium system is in the phase γ when the loading ratio is higher than *0.7*.

This is the most interesting case. The deuterons cross the screening through the *d*-electrons shell. In this respect, we did a numeric simulation where we supposed that the *D-D* potential must be computed on the assumption that the potential (37) well disappears because of the Morse contribution. In fact, if we use a classical plasma model where the D^+ ions are the positive charge and the *d*-electrons the negative one, it is very "realistic" to obtain the following potential:

$$V(r,t) = k\frac{q^2}{r}\cdot\left(V_M(r) - \frac{J\hbar\omega_\gamma R}{r}\right) + Q(t) \tag{47}$$

where *Q(t)* is an unknown perturbative potential. On this topic, we can also add that:

$$\langle Q(t)\rangle_t \approx \frac{W_{\max}}{\sqrt{2}} \tag{48}$$

In the next evaluation it is given as:

$$\langle Q(t)\rangle_t \approx 85eV \tag{49}$$

5. Conclusions

The aim of this section is to present the *D-D* fusion probability normalized to number of events per second regarding the *D-D* interaction in all different phases. More exactly, we seek to compare fusion probability in phases α, β and γ according to the variation of energy between

–50 to *50 eV*. We also consider the role of *d*-electrons screening as a perturbative lattice potential.

This process only involves the case where *Q(t)* is different from zero. It involves a change of the value on the *x*-axes point where the Coulomb barrier takes place; in this case, what we obtain as a final result is that the screening enhances the fusion probability. In order to evaluate the fusion rate (Λ) we applied the following formula:

$$\Lambda = A\Gamma \tag{50}$$

Where Γ is the Gamow factor and A is the nuclear reaction constant obtained from cross sections measured (value used was $10^{22}\ sec^{-1}$).

From an experimental point of view, it is possible to affirm that there are three typologies of experiments in the cold fusion phenomenology [14]:

1) Experiments giving negative results
2) Experiments giving some results (little detection signs with respect to background, fusion probability about 10^{-23} using a very high loading ratio)
3) Experiments giving clear positive results, such as the Fleischmann and Pons experiments.

In our opinion, the experiments of the third type lack accuracy from the experimental point of view. In this sense, we prefer a theoretical model of the controversial phenomenon of cold fusion to explain only experiments of type 1 and 2. In this case it is important to consider the role of the loading ratio in the experimental results. Now, let us begin from the α-phase.

Results for the α-phase are shown in Table 1. As shown there, the theoretical fusion probability is lower than 10^{-74}, that is to say, extremely low. Consequently, we can affirm that no fusion is possible through the loading of a percentage of $x < 0.2$ in the deuterium. The same absence of nuclear phenomenon is compatible for a loading ratio of about *0.7* (Table 2), since in this case the predicted fusion probability is lower than 10^{-42}. These predictions, of course, agree with the experimental results (for $x>0.7$, look at reference [6]). The result of our model is confirmed in the γ-phase, where we can observe some background fluctuations. Due to a high loading ratio, we predict a fusion probability at about 10^{-22} in these background fluctuations. This is a previously unattained result. This is also a very important one for references [7,8], since in those cases the fusion probability was independent of the loading ratio.

To conclude, our aim is also to show that the model proposed in this paper can explain some irregular nuclear traces in solids, unifying nuclear physics with condensed matter. On the other hand, regarding the experiments of type 3, we want to consider other contributions as micro-deformation occurrence, in order to explain the very high fusion rate. The role of micro-crack and impurities linked to the loading ratio will be explored in other speculative works. "The nuclear physics within condensed matter" may be a new device through which an understanding of new productive scientific issues could be possible.

Table 1. Using the α–phase potential (potential 45), the fusion probability has been computed for Pd "Impure" (J ≈ 0.75%), normalized to the number of event/sec for different values of energy (*- 50 eV<E< 50 eV*). Palladium *J ≈ 0.75%* ρ ≈ 0. 34 Å *r'_0=0.7 Å D'= -50 eV*

	$\omega_\alpha \approx 0.0025$ eV	$\omega_\alpha \approx 0.05$ eV	$\omega_\alpha \approx 0.075$ eV	$\omega_\alpha \approx 0.1$ eV
$E \approx -50$	$P \approx 10^{-100}$	$P \approx 10^{-103}$	$P \approx 10^{-100}$	$P \approx 10^{-99}$
$E \approx -40$	$P \approx 10^{-99}$	$P \approx 10^{-101}$	$P \approx 10^{-98}$	$P \approx 10^{-97}$
$E \approx -30$	$P \approx 10^{-97}$	$P \approx 10^{-100}$	$P \approx 10^{-96}$	$P \approx 10^{-96}$
$E \approx -20$	$P \approx 10^{-95}$	$P \approx 10^{-99}$	$P \approx 10^{-94}$	$P \approx 10^{-93}$
$E \approx -10$	$P \approx 10^{-94}$	$P \approx 10^{-97}$	$P \approx 10^{-91}$	$P \approx 10^{-90}$
$E \approx -0$	$P \approx 10^{-92}$	$P \approx 10^{-96}$	$P \approx 10^{-90}$	$P \approx 10^{-86}$
$E \approx 10$	$P \approx 10^{-91}$	$P \approx 10^{-94}$	$P \approx 10^{-87}$	$P \approx 10^{-83}$
$E \approx 20$	$P \approx 10^{-90}$	$P \approx 10^{-92}$	$P \approx 10^{-85}$	$P \approx 10^{-80}$
$E \approx 30$	$P \approx 10^{-89}$	$P \approx 10^{-90}$	$P \approx 10^{-82}$	$P \approx 10^{-78}$
$E \approx 40$	$P \approx 10^{-86}$	$P \approx 10^{-89}$	$P \approx 10^{-80}$	$P \approx 10^{-74}$
$E \approx 50$	$P \approx 10^{-84}$	$P \approx 10^{-87}$	$P \approx 10^{-79}$	$P \approx 10^{-71}$

Table 2. Using the β-potential (potential 46), the fusion probability P has been computed for Pd "Impure" (J ≈ 0.75%), normalized to the number of event/sec for different values energy (*- 50 eV<E<50 eV*). Palladium *J ≈ 0 .75% α ≈ 0. 34 Å r'_0=0.7 Å D'= -50 eV*

	$\omega_\beta \approx 0.125$ eV	$\omega_\beta \approx 0.150$ eV	$\omega_\beta \approx 0.175$ eV	$\omega_\beta \approx 0.2$ eV
$E \approx -50$	$P\ 10^{-83}$	$P \approx 10^{-88}$	$P \approx 10^{-86}$	$P \approx 10^{-81}$
$E \approx -40$	$P \approx 10^{-81}$	$P \approx 10^{-87}$	$P \approx 10^{-85}$	$P \approx 10^{-75}$
$E \approx -30$	$P \approx 10^{-80}$	$P \approx 10^{-86}$	$P \approx 10^{-83}$	$P \approx 10^{-73}$
$E \approx -20$	$P \approx 10^{-79}$	$P \approx 10^{-85}$	$P \approx 10^{-80}$	$P \approx 10^{-70}$
$E \approx -10$	$P \approx 10^{-78}$	$P \approx 10^{-84}$	$P \approx 10^{-74}$	$P \approx 10^{-68}$
$E \approx -0$	$P \approx 10^{-76}$	$P \approx 10^{-82}$	$P \approx 10^{-73}$	$P \approx 10^{-62}$
$E \approx 10$	$P \approx 10^{-75}$	$P \approx 10^{-81}$	$P \approx 10^{-72}$	$P \approx 10^{-60}$
$E \approx 20$	$P \approx 10^{-74}$	$P \approx 10^{-79}$	$P \approx 10^{-71}$	$P \approx 10^{-54}$
$E \approx 30$	$P \approx 10^{-73}$	$P \approx 10^{-76}$	$P \approx 10^{-70}$	$P \approx 10^{-50}$
$E \approx 40$	$P \approx 10^{-72}$	$P \approx 10^{-75}$	$P \approx 10^{-69}$	$P \approx 10^{-45}$
$E \approx 50$	$P \approx 10^{-71}$	$P \approx 10^{-70}$	$P \approx 10^{-65}$	$P \approx 10^{-42}$

Table 3. Using the γ-potential (potential 47), the fusion probability has been computed for Pd "Impure" (J ≈ 0.75%), normalized to the number of event/sec for different values of energy (- 50 eV<E<50 eV). Palladium J≈ 0 .75% ρ ≈ 0. 165 Å r'0=0.35 Å D'= -50 eV

	$\omega_\gamma \approx 0.6$ eV	$\omega_\gamma \approx 0.65$ eV	$\omega_\gamma \approx 0.7$ eV	$\omega_\gamma \approx 0.75$ eV
$E \approx -50$	$P \approx 10^{-71}$	$P \approx 10^{-51}$	$P \approx 10^{-57}$	$P \approx 10^{-50}$
$E \approx -40$	$P \approx 10^{-68}$	$P \approx 10^{-49}$	$P \approx 10^{-54}$	$P \approx 10^{-47}$
$E \approx -30$	$P \approx 10^{-66}$	$P \approx 10^{-47}$	$P \approx 10^{-51}$	$P \approx 10^{-44}$
$E \approx -20$	$P \approx 10^{-62}$	$P \approx 10^{-44}$	$P \approx 10^{-49}$	$P \approx 10^{-41}$
$E \approx -10$	$P \approx 10^{-60}$	$P \approx 10^{-41}$	$P \approx 10^{-46}$	$P \approx 10^{-39}$
$E \approx 0$	$P \approx 10^{-57}$	$P \approx 10^{-39}$	$P \approx 10^{-43}$	$P \approx 10^{-36}$
$E \approx 10$	$P \approx 10^{-54}$	$P \approx 10^{-38}$	$P \approx 10^{-42}$	$P \approx 10^{-33}$
$E \approx 20$	$P \approx 10^{-51}$	$P \approx 10^{-35}$	$P \approx 10^{-40}$	$P \approx 10^{-32}$
$E \approx 30$	$P \approx 10^{-49}$	$P \approx 10^{-32}$	$P \approx 10^{-36}$	$P \approx 10^{-29}$
$E \approx 40$	$P \approx 10^{-47}$	$P \approx 10^{-30}$	$P \approx 10^{-33}$	$P \approx 10^{-25}$
$E \approx 50$	$P \approx 10^{-45}$	$P \approx 10^{-27}$	$P \approx 10^{-30}$	$P \approx 10^{-21}$

Our aim is to propose a theoretical model explaining the experiments implying a high production of energy, so as to be repeatable, reproducible, and shared by the scientific community. Our starting point is the following: the phenomenon of the low-energy fusion critically depends on the interaction between the d-d nuclear system and the D_2 gas system on one side, and the lattice of the palladium on the other side.

In fact, the typical deuterium-plasma interaction of the γ phase grows at the variation of the loading percentage. So, the electrostatic repulsion is weakened. But while the deuterium loading in the gas phase grows, the palladium lattice is deformed.

Other theoretical and experimental studies about the electric field are in progress. To be clearer, here is a brief explanation of the main passages of the lattice reaction: firstly, we have the deformation; secondly, the dislocation; and lastly, the micro-crack.

If the lattice is deformed, the creation of a microscopic electric field occurs within the micro-crack, in which the D^+ and the plasmons collide. Moreover, the deuterium nuclei are accelerated in that field, as it happens in a classic accelerator of nuclear physics. This acceleration can also generate the phenomenon of low-energy fusion.

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