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Theoretical Study of the Phenomenon of Cold Fusion within Condensed Matter and Analysis of Phases (α, β, γ)

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Abstract: The aim of this work is to explain the deuteron-deuteron reactions within palladium lattice by means of the coherence theory of nuclear and condensed matter. The coherence model of condensed matter affirms that within a deuteron-loaded palladium lattice there are three different plasmas: electrons, ions and deuterons plasma. Then, according to the loading percentage x = D/Pd, the deuterium ions can take place on the octahedral sites or in the tetrahedral on the (1, 0, 0)-plane. Further, the present work is concentrated on Palladium because, when subjected to thermodynamic stress, this metal has been seen to give results which are interesting from both the theoretical and experimental points of view. Moreover in Pd lattice we can correlate the deuterium loading with D-Pd system phases (i.e. α, β and γ) by means of theory of condensed matter.

Key words: Condensed matter, dislocations of the ions within the metal, coherence theory, LENR (low energy nuclear reactions).

I. Introduction

The coherence theory of condensed matter is a general theoretical framework, which is widely accepted by most scientists working on cold fusion phenomena. According to this coherence theory of condensed matter [1], it is assumed that the electromagnetic (e.m.) field due to elementary constituents of matter (i.e. ions and electrons) plays a very important role on system dynamics. Considering a coupling between e.m. equations due to charged matter and the Scrödinger equation of field matter operator, it is indeed possible to demonstrate that in proximity of an e.m. frequency ω_0, the matter system features a coherent dynamics. Thus it is possible to define coherence domains, whose length is about $\lambda_{CD} = 2\pi/\omega_0$. Obviously, the simplest model of matter with a coherence domain is a plasma system. In the common plasma theory, a plasma frequency ω_p must be considered, as well as the Debye length measuring the Coulomb force extension, i.e. the coherence domain length. For a system with N charge Q of m mass within a V volume, the plasma frequency can be written as:

$$\omega_p = \frac{Q}{\sqrt{m}}\sqrt{\frac{N}{V}} \tag{1}$$

In this present work, the "nuclear environment" has been studied, which supposedly exists within a D_2-loaded palladium lattice at room temperature, as in accordance with the coherence theory. Traces of nuclear reactions have been observed in a palladium lattice when this is loaded with deuterium gas [2-4]. For this reason, LERN (low energy reaction nuclear) has been defined by many physicists. More robust experiments have shown that in the case of D_2-loaded palladium the following nuclear reactions are more frequent [4, 5]:

$$D + D \rightarrow {}^3H + p + 4.03MeV,$$

$$D + D \rightarrow {}^4He + 23.85MeV \tag{2}$$

In this present work, a "coherence" model is also proposed, by means of which the occurrence of reactions 1 and 2 can be explained in accordance with

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more reliable experiments, as well as their probability. Firstly, an analysis of the environment has been carried out through the coherence theory of matter, i.e. of plasmas which are present within palladium (d-electrons, s-electrons, Pd-ions and D-ions); then, the potential reported in Refs. [6, 7] has been considered, adding the role of lattice perturbations. Thus, a D-D tunneling probability has been computed.

2. Plasmas within Non Loaded Palladium

According to the coherence theory of condensed matter, electron shells are in a coherent regime within a coherent domain in a Pd crystal at room temperature. Indeed, they oscillate in tune with a coherent e.m. field trapped in coherent domains. For this reason, plasmas of s-electrons and d-electrons must be taken into account in order to describe the lattice environment.

2.1 Plasmas of D-Electrons

They are formed by electrons of palladium d-shell. Computing:

$$\omega_d = \frac{e}{\sqrt{m}}\sqrt{\frac{n_d N}{V}} \tag{3}$$

d-electrons plasma frequency is obtained. But according to the coherence theory of matter, this plasma frequency must be adjusted of a factor 1.38. This correction can be easily understood by observing that Eq. (3) is obtained assuming a uniform d-electrons charge distribution. But of course the d-electron plasma is localized in a shell of R radius (that is about 1 Å), so the geometrical contribution is

$$\sqrt{\frac{6}{\pi}} = 1.38 \tag{4}$$

Labeling a renormalized d-electron plasma frequency with ω_{de} [1],

$$\omega_{de} = 41.5eV/\hbar \tag{5}$$

and the maximum oscillation amplitude ξ_d is about 0.5 Å.

2.2 Plasmas of Delocalized S-Electrons

The s-electrons are those neutralizing the adsorbed deuterons ions in a lattice. They are delocalized and their plasma frequency depends on loading ratio (D/Pd percentage), by means of the following formula [1]:

$$\omega_{se} = \frac{e}{\sqrt{m}}\sqrt{\frac{N}{V}} \cdot \sqrt{\frac{x}{\lambda_a}} \tag{6}$$

where,

$$\lambda_a = \left[1 - \frac{N}{V}V_{pd}\right] \tag{7}$$

and V_{pd} is the volume actually occupied by the Pd-atom. As reported in Ref. [1],

$$\omega_{se} \approx x^{1/2} 15.2eV/\hbar \tag{8}$$

As an example, for $x = 0.5$, $\omega_{se} \sim 10.7$ eV/ħ.

2.3 Plasmas of Pd Ions

Finally, plasmas created by Palladium ions forming the lattice structure must be considered. In this case, frequency can be demonstrated as being [1]:

$$\omega_{pd} = 0.1eV \tag{9}$$

3. Plasmas within D_2-Loaded Palladium

It is known that deuterium is adsorbed when placed near to a palladium surface. This loading can be enhanced using electrolytic cells or vacuum chambers working at appropriate pressure [8, 9]. By means of the Theory of Condensed Matter by Preparata, it is assumed that three phases exist concerning the D_2-Pd system, according to a $x = D/Pd$ ratio:

Phase α for $x < 0.1$;

Phase β for $0.1 < x < 0.7$;

Phase γ for $x > 0.7$.

In the α phase, D_2 is in a disordered and non coherent state (D_2 is not charged). Concerning the other phases, the following ionization reaction takes place on the surface, due to lattice e.m.:

$$D_{lattice} \rightarrow D^{+} + e^{-} \quad (10)$$

According to the x = D/Pd loading percentage, deuterium ions can take position on octahedral sites (Fig. 1) or in the tetrahedral ones (Fig. 2) in the (1, 0, 0)-plane. According to the coherence theory, a deuterons plasma in an octahedral site is defined as β-plasma, whereas a deuterons plasma in a tetrahedral one is defined as a γ-plasma.

It is possible to state that frequency of a β-plasma is given by Ref. [1]:

$$\omega_{\beta} = \omega_{\beta 0}(x + 0.05)^{1/2} \quad (11)$$

where

$$\omega_{\beta 0} = \frac{e}{\sqrt{m_D}}\left(\frac{N}{V}\right)^{1/2}\frac{1}{\lambda_a^{1/2}} = \frac{0.15}{\lambda_a^{1/2}} eV/\hbar \quad (12)$$

As an example, for $\lambda_a = 0.4$ and $x = 0.5$, $\omega_\beta = 0.168$ eV/ħ.

In tetrahedral sites, D^+ can occupy the thin disk encompassing two sites (Fig. 3), thus forming a barrier to D^+ ions. Notice that the electrons of the d-shell oscillate past an equilibrium distance y_0 (about 1.4 Å), thus embedding ions in a static cloud of negative charge which can screen the Coulomb barrier. As reported in Ref. [1],

$$\omega_{\gamma} = \sqrt{\frac{4Z_{eff}\alpha}{m_D y_0^2}} \approx 0.65 eV/\hbar \quad (13)$$

This frequency obviously depends also on the chemical conditions of palladium (impurities, temperature etc.). 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^+ is located, giving rise to a screening potential $W(t)$ whose profile is reported in Fig. 4. It must be highlighted that the γ-phase depends on the x value and that this new phase has been experimentally observed [10].

The new phase γ is a very important one in LERN investigation. In fact, many cold fusion scientists

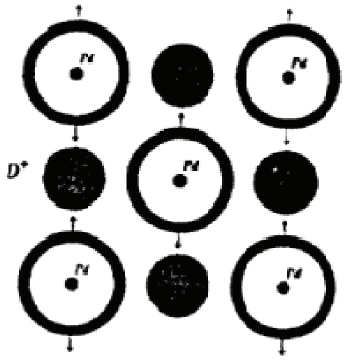

Fig. 1 The octahedral sites of a Pd lattice where deuterons take position.

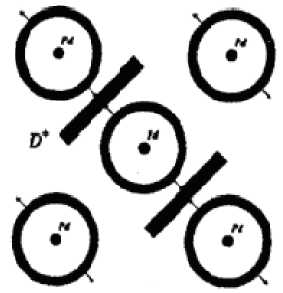

Fig. 2 The thin disks of tetrahedral sites of a Pd lattice where deuterons take place.

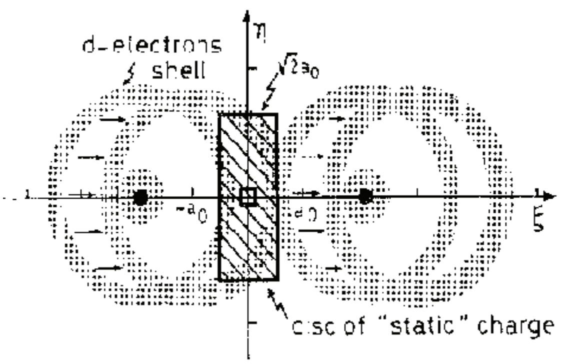

Fig. 3 Possible d-electron plasma oscillation in a Pd lattice.

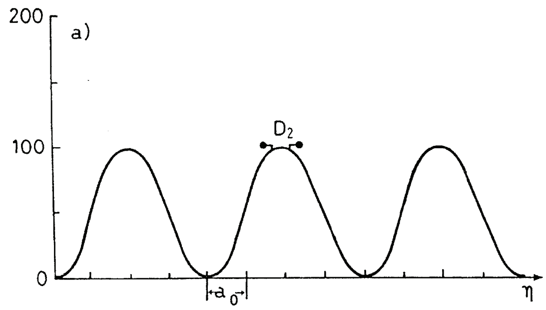

Fig. 4 The profile of the electrostatic potential in a arbitrarily direction η.

claim that the main point of cold fusion protocol is that the D/Pd loading ratio must be higher than 0.7, i.e. that deuterium must take position in tetrahedral sites.

4. D-D Potential

As shown in Ref. [6], the phenomena of fusion between nuclei of deuterium in a crystalline lattice of a metal is conditioned by structural features, by the dynamic conditions of the system, and also by the concentration of impurities which are present in the examined metal.

A study has been held of the curves of the interaction potential between deuterons (including a deuteron-plasmon contribution) in the case of three typical metals (Pd, Pt and Ti). A three-dimensional model showed that the height of the Coulomb barrier decreases on varying the total energy and the concentration of impurities which are present in the examined metal.

A potential accounting for both the role of temperature and impurities is given by the following expression [6]:

$$V(r) = k_0 \frac{q^2}{r} \cdot M_d \left(V(r)_M - \frac{J\ kT\ R}{r} \right) \quad (14)$$

In Eq. (14), the $V(r)_M$ Morse potential is given by:

$$V(r)_M = (J/\zeta)\left\{\exp\left(-2\varphi(r-r_0)\right) - 2\exp\left(-\varphi(r-r_0)\right)\right\} \quad (15)$$

Here parameters φ and r_0 depend on the dynamic conditions of the system, ζ is a parameter depending on the structural features of the lattice, i.e. number of “d” band electrons and type of lattice symmetry, varying between 0.015 and 0.025.

Obviously the Morse potential is used in an interval including an inner turning point r_a and continuing towards $r = 0$, where it approaches the Coulomb potential (Fig. 5).

In Ref. [6], a fusion probability is obtained by means of the following formula (α is the zero crossing r-value of potential):

$$|P|^2 = \exp\left(-2\int_0^{\alpha} K(r)\,dr\right) \quad (16)$$

where,

$$K(r) = \sqrt{2\mu[E - V(r)]/\hbar^2} \quad (17)$$

This fusion probability is obtained using the reasonable value of 10^{21} min^{-1} for the nuclear rate, and it is normalized to a number of events per minute of 10^{-25} for $\alpha = 0.34$ Å, $E = 250$ eV, $T = 300$ K and $J = 0.75$ (high impurities case). Many experiments confirmed these fusion rate values concerning reactions 1 and 2 [11].

In this present work, the role of potential (14) is studied in accordance with the coherence theory of condensed matter, in the three different phases α, β and γ.

In this theoretical framework, two key points need a clarification:

(1) What KT is.

(2) What the role of electrons and ions plasmas is.

Concerning the first point and according to different deuteron-lattice configurations, KT can be:

(1) The lattice temperature if we consider deuterons in the α-phase.

(2) ω_β if we consider deuterons in the β-phase.

(3) ω_γ if we consider deuterons in the γ-phase.

The second point is a more controversial issue. In fact, the lattice environment is a mixture of coherent plasmas (Pd ions, electrons and deuterons plasmas) at different temperatures, due to different masses. Thus, describing an emerging potential is a very hard task. The method proposed in this present work is that of considering the total contribution of lattice environment at D-D interaction (i.e. V_{tot}) as a random potential $Q(t)$. In accordance with this model,

$$V_{tot}(t) = V(r) + Q(t) \quad (18)$$

obviously assuming that:

$$\langle V_{tot}(t)\rangle_t \neq 0 \quad (19)$$

That is, a second order potential contribution $Q(t)$ is supposed to be a periodic potential whose frequency will be labeled by ω_Q, oscillating between the maximum value Q_{max} and 0.

The role of potential $Q(t)$ is that of increasing or decreasing the barrier. The plot of potential V_{tot} for two different values of $Q(t)$ is reported in Fig. 6.

This means that the following main cases may occur in accordance with ω_Q and with the energy of incoming particles to the barrier:

(1) The particle crosses the barrier in the point α;

(2) The particle crosses the barrier in the point α'.

Scenario (2) can be regarded as a worst case to obtain a high tunneling probability, and scenario (1) as a best case.

To determine the model parameters, some hypothesis must be suggested on $Q(t)$ and ω_Q. In this present work, an approximation is made of $Q(t)$ as equivalent to a screening potential $W(t)$ due to d-electrons, as reported in Fig. 5. This means that $\omega_Q \sim \omega_d$. Obviously, there is a strong dependence between the scenario and the deuteron phase, since $Q(t)$ is only the d-electrons screening potential, at first order. To resume, the following cases may occur in a palladium lattice according to the loading ratio:

(i) α-phase

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

0.02 eV < $\hbar\omega_\alpha$ < 0.2 eV

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

$$V(r) = const\frac{q^2}{r}\cdot M_d\left(V_M(r) - \frac{J\hbar\omega_\alpha R}{r}\right) \quad (20)$$

Eq. (20) has been partially evaluated in Ref. [6], only focusing on the dependence of a tunneling probability on impurities which are present within the lattice. In this present work, a correlation is made between potential features and loading ratio. Numerical results are shown in Section 6.

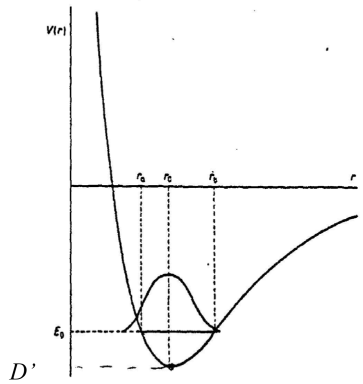

Fig. 5 D-D potential features using a Morse potential.

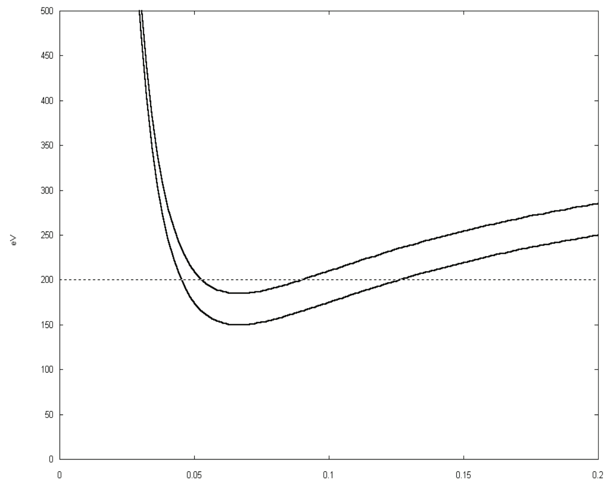

Fig. 6 Potential features for two different arbitrary values of *Q*(*t*).

(ii) β-phase

When x is higher than 0.1 but lower than 0.7, phase β happens. The interaction takes place between deuteron ions oscillating by the following energy values:

0.1 eV < $\hbar\omega_\beta$ < 0.2 eV

In this case $W(t)$ is zero, so the potential is given by Eq. (21):

$$V(r) = const\frac{q^2}{r}\cdot M_d\left(V_M(r) - \frac{J\hbar\omega_\beta R}{r}\right) \quad (21)$$

Comparing Eqs. (20) and (21), it seems very clear that the weight of impurities is more important in the β-phase. This conclusion is obviously in accordance with Refs. [6, 7], where the role played by temperature in the tunneling effect was studied.

(iii) γ-phase

Finally, the deuteron-palladium system is in the γ phase when the loading ratio is higher than 0.7. According to a synchronism between phase oscillations of deuteron and d-electrons plasmas, the following two cases must be considered:

Case 1: $Q(t) = 0$

In this case, the potential is a natural extension of Eq. (14), and can be written as:

$$V(r) = const\frac{q^2}{r}\cdot M_d\left(V_M(r) - \frac{J\hbar\omega_\gamma R}{r}\right) \quad (22)$$

Case 2: $Q(t) \neq 0$

This is the more interesting case. It happens when ω_γ is about ω_Q and obviously when the respective oscillations are in phase. Deuterons undergo a screening due to the d-electrons shell, so a supposition is made that D-D potential must be computed assuming a disappearance of the well which is present in potential (14), due to Morse contribution. Indeed, using a classical plasma model where D^+ ions are the positive charge and d-electrons are the negative one, it is extremely reasonable to suppose that the following potential must be used:

$$V(r,t) = const\frac{q^2}{r}\cdot M_d\left(\frac{\alpha}{|\vec{r}|}e^{-\frac{|\vec{r}|}{\lambda_D}} - \frac{J\hbar\omega_\gamma R}{r}\right) + Q(t) \quad (23)$$

where,

$$V_C(\vec{r}) = \frac{\alpha}{|\vec{r}|}e^{-\frac{|\vec{r}|}{\lambda_D}} \quad (24)$$

and λ_D is the Debye length of this classical plasma. Notice that $Q(t)$ is an unknown perturbative potential. About this, it can only be stated that:

$$\langle Q(t)\rangle_t \approx \frac{W_{max}}{\sqrt{2}} \quad (25)$$

As previously said, this is supposed to be a screening potential due to d-electrons and its role is supposed to be that of reducing the repulsive barrier.

5. The Barrier Crossing Treatment

A discussion follows on how to handle the crossing of the barrier in the γ-phase and when $Q(t)$ is different from zero. The starting point in any case is the Schrödinger equation:

$$\frac{\hbar^2}{2\mu}\Psi''(r)\left[E - V_{tot}(r,t)\right]\Psi(r) = 0 \quad (26)$$

Nevertheless, this is a difficult problem to solve. To handle this topic in a simple way, it can be observed that using $V_{tot}(r,t) = V(r) + W_{max}/\sqrt{2}$, this problem concerns four main energy values E_1, E_2, E_3 and E_4 (check Fig. 7). This problem is equivalent to the treating of a double barrier case. From Ref. [12],

$$E_1 = \text{a few eV} \quad (27)$$

$$E_2 = -D\left(1 - \frac{\gamma\hbar}{\sqrt{2\mu D}}\left(\mu + \frac{1}{2}\right)\right)^2 \quad (28)$$

$$E_3 \sim \left(\frac{m_e}{M_N}\right)E_1 \sim \frac{1}{1000}eV \quad (29)$$

$$E_4 = D' \quad (30)$$

γ is the constant of metal anharmonicity and ν is the vibrational constant. Another important quantity is D', which is the depth of the potential well. According to the Morse potential (15), this is J/ξ. Now building an energy tensor E_{ij}:

$$E_{11} = E_1$$
$$E_{22} = E_2$$
$$E_{33} = E_3$$
$$E_{44} = E_4$$
$$E_{ij} = E_i - E_j$$
$$E_{ij} = -E_{ji}$$

A square quadratic energy value can be defined:

$$\langle E\rangle = \sqrt{\frac{trE_{ij}E^{ij}}{4}} \quad (31)$$

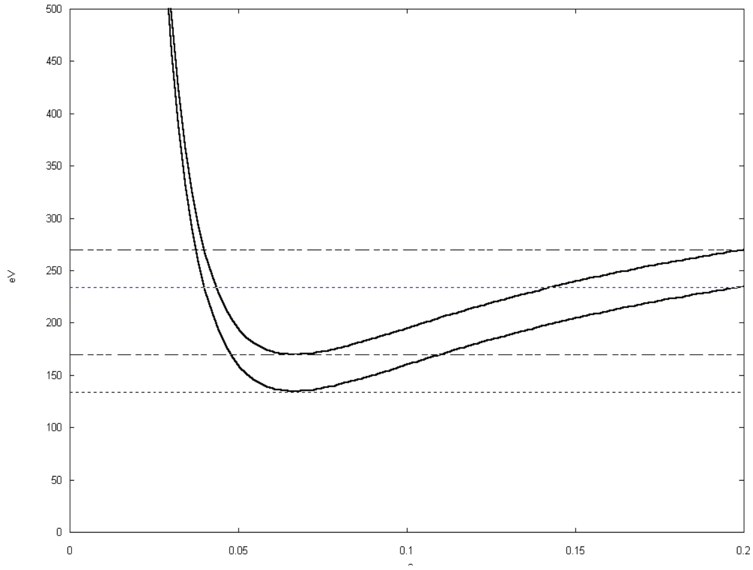

Fig. 7 Features of $V(r)$ and $V(r)+W_{max}/\sqrt{2}$.

and a dispersion:

$$\sigma = \sqrt{\frac{\sum_{i \neq j} E_{ij} E^{ij}}{4}} \tag{32}$$

If we neglect the term $Q(t)$ and consider only the random feature of deuteron energy, the following could be a reasonable value for $K(r)$:

$$K(r) = \frac{1}{\hbar}\sqrt{2\mu\left[V(r) - \left(\sqrt{\frac{TrE_{ij}E^{ji}}{4}} \pm \sigma\right)\right]} \tag{33}$$

And finally,

$$P(\alpha) = \exp\left(-2\int_0^{\alpha} K(r)dr\right) \tag{34}$$

But according to statistical treatment,

$$P = P(\alpha, \langle E \rangle, \sigma) \tag{35}$$

where,

$$\alpha = \alpha[Q(t)] \tag{36}$$

as already seen concerning the γ phase. Since the greater contribution to $Q(t)$ is supposedly due to a screening effect of d-electrons in the γ-phase (i.e. of random potential), any other case can be neglected and only the following two cases must be considered (i.e. featuring a double barrier approximation):

(1) $Q(t) = 0 \rightarrow \alpha = 0.34$ Å

(2) $Q(t) \neq 0 \rightarrow \alpha = 0.16$ Å

Of course, case (2) is the more advantageous to obtain a high tunneling probability.

6. Results and Discussion

A presentation follows of the D-D fusion probability normalized to number of events per minute concerning D-D interaction in all different phases. More exactly, fusion probability in phases α, β and γ are compared, using a reasonable square average value of 200 eV and a σ value of 50 eV, in order to cross potential (14) in all four points E_1, E_2, E_3 and E_4. The role of d-electron screening is also considered as a perturbative lattice potential. This treatment only concerns the case when $Q(t)$ is different from zero, and implies changing the time-dependent problem of a tunneling effect into a double barrier problem. To resume, the emerging of a double barrier in the γ-phase is a new "physics fact". Notice that cold fusion scientists built up their expectations about a new γ-phase, because screening enhances the fusion probability. From an experimental point of view, it is possible to state that three typologies of experiments exist in the phenomenology of cold fusion [13]:

(1) Those that have given negative results.

(2) Those that have given some results (little signs of detection with respect to background, fusion probability of about 10^{-25}), using a very high loading ratio.

(3) Those that have given clear positive results, like Fleischmann and Pons experiments.

Nevertheless, our opinion is that the experiments like in point (3) are lacking in accuracy from an experimental point of view. For this reason, we believe that this theoretical model of the controversial phenomenon of cold fusion must only explain the experiments like in point (1) and (2). In this case, the role of loading ratio must be considered in the experimental results.

Results about the α-phase are shown in Table 1. In this case, it can be observed that the theoretical fusion probability is lower than 10^{-74}, which is very small. It is possible to state that if the deuterium is loaded with a $x < 0.2$ percentage, no fusion event is observed! The same absence of nuclear phenomenon is compatible with a loading ratio of about 0.7 (Table 2), since the predicted fusion probability is less than 10^{-42} in this

Table 1 Fusion probability has been computed for "impure" Pd ($J \approx$ 0.75%), using a α-potential (potential 20), and normalized to a number of event/min for different values of energy ($\sigma = \pm 50$ eV).

Palladium $J \approx 0.75\%$, $\alpha \approx 0.34$ Å, $\langle E \rangle = 200$ eV

$\omega_\alpha \approx 0.05$ eV	$\omega_\alpha \approx 0.1$ eV	$\omega_\alpha \approx 0.15$ eV	$\omega_\alpha \approx 0.2$ eV
$\sigma \approx -50$ P $\approx 10^{-100}$	$\sigma \approx -50$ P $\approx 10^{-103}$	$\sigma \approx -50$ P $\approx 10^{-100}$	$\sigma \approx -50$ P $\approx 10^{-99}$
$\sigma \approx -40$ P $\approx 10^{-99}$	$\sigma \approx -40$ P $\approx 10^{-101}$	$\sigma \approx -40$ P $\approx 10^{-98}$	$\sigma \approx -40$ P $\approx 10^{-97}$
$\sigma \approx -30$ P $\approx 10^{-97}$	$\sigma \approx -30$ P $\approx 10^{-100}$	$\sigma \approx -30$ P $\approx 10^{-96}$	$\sigma \approx -30$ P $\approx 10^{-96}$
$\sigma \approx -20$ P $\approx 10^{-95}$	$\sigma \approx -20$ P $\approx 10^{-99}$	$\sigma \approx -20$ P $\approx 10^{-94}$	$\sigma \approx -20$ P $\approx 10^{-93}$
$\sigma \approx -10$ P $\approx 10^{-94}$	$\sigma \approx -10$ P $\approx 10^{-97}$	$\sigma \approx -10$ P $\approx 10^{-91}$	$\sigma \approx -10$ P $\approx 10^{-90}$
$\sigma \approx 0$ P $\approx 10^{-92}$	$\sigma \approx 0$ P $\approx 10^{-96}$	$\sigma \approx 0$ P $\approx 10^{-90}$	$\sigma \approx 0$ P $\approx 10^{-86}$
$\sigma \approx 10$ P $\approx 10^{-91}$	$\sigma \approx 10$ P $\approx 10^{-94}$	$\sigma \approx 10$ P $\approx 10^{-87}$	$\sigma \approx 10$ P $\approx 10^{-83}$
$\sigma \approx 20$ P $\approx 10^{-90}$	$\sigma \approx 20$ P $\approx 10^{-92}$	$\sigma \approx 20$ P $\approx 10^{-85}$	$\sigma \approx 20$ P $\approx 10^{-80}$
$\sigma \approx 30$ P $\approx 10^{-89}$	$\sigma \approx 30$ P $\approx 10^{-90}$	$\sigma \approx 30$ P $\approx 10^{-82}$	$\sigma \approx 30$ P $\approx 10^{-78}$
$\sigma \approx 40$ P $\approx 10^{-86}$	$\sigma \approx 40$ P $\approx 10^{-89}$	$\sigma \approx 40$ P $\approx 10^{-80}$	$\sigma \approx 40$ P $\approx 10^{-74}$
$\sigma \approx 50$ P $\approx 10^{-84}$	$\sigma \approx 50$ P $\approx 10^{-87}$	$\sigma \approx 50$ P $\approx 10^{-79}$	$\sigma \approx 50$ P $\approx 10^{-71}$

Table 2 Fusion probability has been computed for "impure" Pd ($J \approx$ 0.75%), using a β-potential (potential 21), and normalized to a number of event/min for different values of energy ($\sigma = \pm 50$ eV).

Palladium $J \approx 0.75\%$, $\alpha \approx 0.34$ Å, $\langle E \rangle = 200$ eV

$\omega_\beta \approx 0.33$ Å	$\omega_\beta \approx 0.68$ Å	$\omega_\beta \approx 1.03$ Å	$\omega_\beta \approx 1.38$ Å
$\sigma \approx -50$ P $\approx 10^{-83}$	$\sigma \approx -50$ P $\approx 10^{-88}$	$\sigma \approx -50$ P $\approx 10^{-86}$	$\sigma \approx -50$ P $\approx 10^{-81}$
$\sigma \approx -40$ P $\approx 10^{-81}$	$\sigma \approx -40$ P $\approx 10^{-87}$	$\sigma \approx -40$ P $\approx 10^{-85}$	$\sigma \approx -40$ P $\approx 10^{-75}$
$\sigma \approx -30$ P $\approx 10^{-80}$	$\sigma \approx -30$ P $\approx 10^{-86}$	$\sigma \approx -30$ P $\approx 10^{-83}$	$\sigma \approx -30$ P $\approx 10^{-73}$
$\sigma \approx -20$ P $\approx 10^{-79}$	$\sigma \approx -20$ P $\approx 10^{-85}$	$\sigma \approx -20$ P $\approx 10^{-80}$	$\sigma \approx -20$ P $\approx 10^{-70}$
$\sigma \approx -10$ P $\approx 10^{-78}$	$\sigma \approx -10$ P $\approx 10^{-84}$	$\sigma \approx -10$ P $\approx 10^{-74}$	$\sigma \approx -10$ P $\approx 10^{-68}$
$\sigma \approx 0$ P $\approx 10^{-76}$	$\sigma \approx 0$ P $\approx 10^{-82}$	$\sigma \approx 0$ P $\approx 10^{-73}$	$\sigma \approx 0$ P $\approx 10^{-62}$
$\sigma \approx 10$ P $\approx 10^{-75}$	$\sigma \approx 10$ P $\approx 10^{-81}$	$\sigma \approx 10$ P $\approx 10^{-72}$	$\sigma \approx 10$ P $\approx 10^{-60}$
$\sigma \approx 20$ P $\approx 10^{-74}$	$\sigma \approx 20$ P $\approx 10^{-79}$	$\sigma \approx 20$ P $\approx 10^{-71}$	$\sigma \approx 20$ P $\approx 10^{-54}$
$\sigma \approx 30$ P $\approx 10^{-73}$	$\sigma \approx 30$ P $\approx 10^{-76}$	$\sigma \approx 30$ P $\approx 10^{-70}$	$\sigma \approx 30$ P $\approx 10^{-50}$
$\sigma \approx 40$ P $\approx 10^{-72}$	$\sigma \approx 40$ P $\approx 10^{-75}$	$\sigma \approx 40$ P $\approx 10^{-69}$	$\sigma \approx 40$ P $\approx 10^{-45}$
$\sigma \approx 50$ P $\approx 10^{-71}$	$\sigma \approx 50$ P $\approx 10^{-70}$	$\sigma \approx 50$ P $\approx 10^{-65}$	$\sigma \approx 50$ P $\approx 10^{-42}$

Table 3 Fusion probability has been computed for "impure" Pd (*J* ≈ 0.75%), using γ-potential with *Q(t)* =0 (potential 22), and normalized to a number of event/min for different values of energy (σ = ±50 eV).

Palladium $J \approx 0.75\%$, $\alpha \approx 0.34$ Å, <*E*> = 200 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
$\sigma \approx 150$ P $\approx 10^{-75}$	$\sigma \approx 150$ P $\approx 10^{-55}$	$\sigma \approx 150$ P $\approx 10^{-58}$	$\sigma \approx 150$ P $\approx 10^{-65}$
$\sigma \approx 160$ P $\approx 10^{-74}$	$\sigma \approx 160$ P $\approx 10^{-52}$	$\sigma \approx 160$ P $\approx 10^{-57}$	$\sigma \approx 160$ P $\approx 10^{-62}$
$\sigma \approx 170$ P $\approx 10^{-73}$	$\sigma \approx 170$ P $\approx 10^{-47}$	$\sigma \approx 170$ P $\approx 10^{-53}$	$\sigma \approx 170$ P $\approx 10^{-59}$
$\sigma \approx 180$ P $\approx 10^{-70}$	$\sigma \approx 180$ P $\approx 10^{-45}$	$\sigma \approx 180$ P $\approx 10^{-48}$	$\sigma \approx 180$ P $\approx 10^{-55}$
$\sigma \approx 190$ P $\approx 10^{-69}$	$\sigma \approx 190$ P $\approx 10^{-43}$	$\sigma \approx 190$ P $\approx 10^{-44}$	$\sigma \approx 190$ P $\approx 10^{-50}$
$\sigma \approx 200$ P $\approx 10^{-68}$	$\sigma \approx 200$ P $\approx 10^{-42}$	$\sigma \approx 200$ P $\approx 10^{-54}$	$\sigma \approx 200$ P $\approx 10^{-44}$
$\sigma \approx 210$ P $\approx 10^{-66}$	$\sigma \approx 210$ P $\approx 10^{-41}$	$\sigma \approx 210$ P $\approx 10^{-46}$	$\sigma \approx 210$ P $\approx 10^{-38}$
$\sigma \approx 220$ P $\approx 10^{-64}$	$\sigma \approx 220$ P $\approx 10^{-40}$	$\sigma \approx 220$ P $\approx 10^{-42}$	$\sigma \approx 220$ P $\approx 10^{-35}$
$\sigma \approx 230$ P $\approx 10^{-63}$	$\sigma \approx 230$ P $\approx 10^{-39}$	$\sigma \approx 230$ P $\approx 10^{-35}$	$\sigma \approx 230$ P $\approx 10^{-31}$
$\sigma \approx 240$ P $\approx 10^{-61}$	$\sigma \approx 240$ P $\approx 10^{-37}$	$\sigma \approx 240$ P $\approx 10^{-34}$	$\sigma \approx 240$ P $\approx 10^{-28}$
$\sigma \approx 250$ P $\approx 10^{-60}$	$\sigma \approx 250$ P $\approx 10^{-35}$	$\sigma \approx 250$ P $\approx 10^{-31}$	$\sigma \approx 250$ P $\approx 10^{-25}$

Table 4 Fusion probability has been computed for "impure" Pd (*J* ≈ 0.75%), using a Debye potential (potential 24), and normalized to a number of event/min for different values of energy (σ = ± 50 eV).

Palladium $J \approx 0.75\%$, $\alpha \approx 0.34$ Å, <*E*> = 200 eV

$\lambda_D \approx 0.3175$ Å	$\lambda_D \approx 0.635$ Å	$\lambda_D \approx 0.9525$ Å	$\lambda_D \approx 1.27$ Hz Å
$\sigma \approx -50$ P $\approx 10^{-65}$	$\sigma \approx -50$ P $\approx 10^{-62}$	$\sigma \approx -50$ P $\approx 10^{-53}$	$\sigma \approx -50$ P $\approx 10^{-53}$
$\sigma \approx -40$ P $\approx 10^{-62}$	$\sigma \approx -40$ P $\approx 10^{-58}$	$\sigma \approx -40$ P $\approx 10^{-50}$	$\sigma \approx -40$ P $\approx 10^{-52}$
$\sigma \approx -30$ P $\approx 10^{-60}$	$\sigma \approx -30$ P $\approx 10^{-56}$	$\sigma \approx -30$ P $\approx 10^{-46}$	$\sigma \approx -30$ P $\approx 10^{-50}$
$\sigma \approx -20$ P $\approx 10^{-55}$	$\sigma \approx -20$ P $\approx 10^{-55}$	$\sigma \approx -20$ P $\approx 10^{-42}$	$\sigma \approx -20$ P $\approx 10^{-46}$
$\sigma \approx -10$ P $\approx 10^{-53}$	$\sigma \approx -10$ P $\approx 10^{-53}$	$\sigma \approx -10$ P $\approx 10^{-40}$	$\sigma \approx -10$ P $\approx 10^{-43}$
$\sigma \approx 0$ P $\approx 10^{-52}$	$\sigma \approx 0$ P $\approx 10^{-51}$	$\sigma \approx 0$ P $\approx 10^{-36}$	$\sigma \approx 0$ P $\approx 10^{-37}$
$\sigma \approx 10$ P $\approx 10^{-51}$	$\sigma \approx 10$ P $\approx 10^{-50}$	$\sigma \approx 10$ P $\approx 10^{-35}$	$\sigma \approx 10$ P $\approx 10^{-33}$
$\sigma \approx 20$ P $\approx 10^{-50}$	$\sigma \approx 20$ P $\approx 10^{-49}$	$\sigma \approx 20$ P $\approx 10^{-32}$	$\sigma \approx 20$ P $\approx 10^{-28}$
$\sigma \approx 30$ P $\approx 10^{-49}$	$\sigma \approx 30$ P $\approx 10^{-46}$	$\sigma \approx 30$ P $\approx 10^{-31}$	$\sigma \approx 30$ P $\approx 10^{-25}$
$\sigma \approx 40$ P $\approx 10^{-47}$	$\sigma \approx 40$ P $\approx 10^{-43}$	$\sigma \approx 40$ P $\approx 10^{-30}$	$\sigma \approx 40$ P $\approx 10^{-20}$
$\sigma \approx 50$ P $\approx 10^{-45}$	$\sigma \approx 50$ P $\approx 10^{-40}$	$\sigma \approx 50$ P $\approx 10^{-29}$	$\sigma \approx 50$ P $\approx 10^{-17}$

case. These predictions are obviously in agreement with the experimental results. But for $x > 0.7$, a full range of valid experiments on cold fusion has reported some background spikes (check Ref. [10] as an example). A remarkable result of our model is shown in Table 3: some background fluctuations can be observed in the γ-phase, since we predict a fusion probability about 10^{-25} due to a very high loading ratio. This represents a new result with respect to Refs. [6, 7], since in those cases the fusion probability was independent of loading ratio. In order to predict a very noteworthy nuclear evidence (about 10^{-17}), ω_γ must be comparable with ω_Q (Table 4). Only under this condition can the screening potential enhance the tunneling probability and the D-D interaction become a like-Debye potential. The condition allowing this equivalence result of ω_γ to ω_Q will be discussed in another paper. Here, we only underline that it is a very unlikely condition.

7. Conclusions

As a conclusion, we have shown that the model proposed in this present paper can explain some anomalous nuclear traces in solids, but definitely jeopardize any hope about the possibility of controlled fusion reactions in matter.

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