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# A possible mechanism of cold fusion

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**Abstract.** A possible mechanism for the occurrence of nuclear fusion at room temperature is presented. Neutralization of the positive charge of the deuteron nucleus by its orbiting electron due to large enhancement of effective mass results in the vanishing of the Coulomb barrier which facilitates fusion at room temperature.

**Keywords.** Deuteron nuclei; cold fusion.

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During the last one month, tremendous excitement has been generated by the experiment of Fleischmann and Pons at Utah University, who claim that deuterons undergo fusion in a very simple test tube experiment at room temperature. Their experiment is as follows. Heavy water i.e. $D_2O$ is taken in a container in which two electrodes made up of palladium (Pd) and platinum (Pt) metals respectively are installed. Then electric current is passed through. $D_2O$ molecule breaks up into deuteron and oxygen. The deuterons are attracted towards Pd electrode, and get stored up there. Traditionally Pd has been known to be a good absorber of hydrogen. Thus, deuteron which has the same properties as hydrogen except that its mass is larger because of the extra neutron, gets absorbed in it. So, density of deuterons in Pd goes on increasing until, at a critical threshold, pressure forces them together so hard that they fuse. A large amount of energy is released resulting in the Pd electrode getting evaporated. Detection of neutron confirms that nuclear fusion takes place in this reaction. This claim has sent shock waves throughout the scientific world, and attempts to reproduce this astounding result in different laboratories in the world are underway. To date several laboratories in different countries have reported their confirmation of the claim of Fleischmann and Pons. In India, Reactor Research Centre at Kalpakkam and Tata Institute of Fundamental Research, Bombay have reported their success in this regard. Inspite of such reports of confirmation by various groups, we would like to state that, this phenomenon has not been universally accepted at the moment.

It has been a great puzzle to almost all, that, such a process could take place in so simple an experiment. The main reason has been that the two deuteron nuclei will repel each other because of the Coulomb force acting between them. This repulsion will give rise to a Coulomb barrier

$$C_B = e^2/R_B, \tag{1}$$

where $R_B$ is the fusion radius. It is defined by the distance when fusion may take place if the two nuclei come closer than that. The value of $C_B$ is about $\approx 0{\cdot}4$ MeV. This is the hurdle on the path of fusion of the two deuterons. This will be overcome if the deuteron is given an equivalent amount of kinetic energy, which is achieved in the sun through its temperature of more than 100 million degrees centigrade. In the laboratory, the efforts have been underway for the last two decades to achieve fusion by heating plasma, without considerable success as yet. In view of this, the experiment of Fleischmann and Pons has been considered epoch making which promises inexhaustible source of clean energy for the world. In this note we examine, whether such a process is plausible, and can be explained in terms of our existing knowledge of nuclear and condensed matter physics.

We view the process to be greatly influenced by the electron in deuterium atom. As in standard electrolysis process, a deuteron, on reaching the Pd electrode, will acquire an electron and form neutral deuterium atom which subsequently will be lodged in the inter lattice space of Pd. With the progress of electrolysis, more and more of deuterium atoms will be thrust into this space resulting in a deuterium solid, or equivalently, regular arrays of deuterium atoms. The electron in the deuterium atom will see this regular array as a Bloch potential. This results in the electron acquiring an effective mass. Depending upon the configuration of the deuterium atoms, it is quite possible that the effective mass could be quite large leading to the shrinkage of 1*s* Bohr orbit. This shrinkage would continue unabatedly with the increase of the packing of the deuterium atoms in the inter-lattice space. This may finally lead to the scenario in which the negative charge distribution of the electron may overlap significantly with the positive charge distribution of the deuteron resulting in the neutralization of the positive charge. (It may be remembered that deuteron is a very loosely bound system with root mean square radius of 4·2 fm. Fifty per cent of the time the neutron and proton spend outside the range of the nuclear force). This neutralization will reduce the Coulomb barrier progressively. Finally, it may so happen that the barrier disappears altogether or may became too small to be overcome easily by the neighbouring deuteron with its thermal energy. Tunneling process will also be greatly enhanced. Thus, the hurdle of the barrier being greatly weakened, fusion becomes inevitable. In the following we quantitatively investigate if our above picture is in confirmity with our knowledge of solid and nuclear systems.

Consider an array of deuterium atoms placed at a distance of $R_0$ from each other in the inter-lattice space of Pd. The value of the energy overlap integral of the 1*s* orbitals of two successive *D* atoms is given by (Kittel 1976).

$$I = 2(1 + R_0/a_0)\exp(-R_0/a_0)[me^4/(2\hbar^2)], \tag{2}$$

where $m$ is the mass of the electron and $a_0 = \hbar^2/me^2$ is the Bohr radius of the 1*s* state. In the standard band theory, the tight binding approximation leads to an effective mass (Kittel 1976)

$$m^* = \frac{\hbar^2}{2IR_0^2}. \tag{3}$$

Our contention is that the effective mass changes the Bohr radius to $a_0^* = \hbar^2/(m^* e^2)$

and that in turn affects the energy overlap integral $I$, which becomes

$$I(m^*) = 2\left(1 + \frac{R_0}{a_0^*}\right)\exp(-R_0/a_0^*)[m^* e^4/(2\hbar^2)]. \tag{4}$$

The effective mass $m^*$ is now obtained by solving simultaneously (3) and (4). Note that in (3), $I$ is to be interpreted as $I(m^*)$ given by (4).

Defining a variable

$$y = \frac{R_0}{a_0} \cdot \frac{m}{m^*},$$

we rewrite (3) and (4) in dimensionless forms as

$$I = (a_0/R_0)y, \tag{5}$$

and

$$I = 2\left(1 + \frac{1}{y}\right)\exp(-1/y). \tag{6}$$

The straight line given by (5) forms a tangent to the curve represented by (6) at the point $I = 1{\cdot}04$, $y = 0{\cdot}62$, with the slope $a_0/R_0$ of about 1.7.

In figure 1, we show the curve represented by (6) as the solid curve, and a straight line representing (5) by the dashed line. It is clear that the linear graph of (5) will intersect this curve at points other than the origin if $a_0/R_0$ is small. However, for $a_0/R_0$ greater than a critical value, which is approximately 1·7, the dotted line has the only intersection at $y = 0$. Hence, for this packing the effective mass becomes tremendously large supporting the picture proposed above. The dotted area corresponds to $a_0/R_0$ smaller than the above critical value which will favour fusion. The typical interatomic

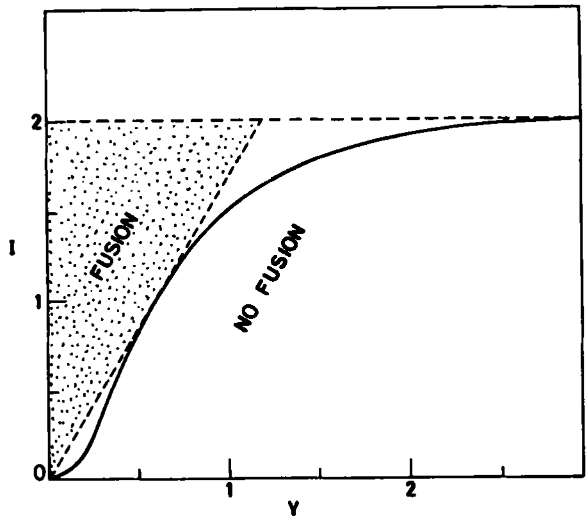

**Figure 1.** Plot of functions represented by eqs (5) (dashed line) and (6) (solid curve). The dotted area represents those values of $y$ for which fusion is favoured.

distances in a solid composed of light mass atoms are about 1·5 Å. So the condition for fusion obtained above is in the realm of possibility.

We thus conclude that in a very simple-minded calculation it can be seen that if the packing of deuteron is sufficiently tight ($a_0/R_0 > 1{\cdot}7$), the effective mass can become enormously large and the electronic length scale can become of the same order of magnitude as the nuclear length scale. This leads to good effective charge screening of the deuteron, and an effective lowering of the Coulomb barrier facilitating cross over by the neighbour with thermal energy. At this stage tunneling also becomes equally easy and greatly favoured.

## Reference

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